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GIANT LAND REPTILES.

By R. LYDEKKER, B.A.CANTAB.

(*Continued from page* 225.)

THE third great group of Giant Land Reptiles was first definitely brought under the notice of the scientific world by the late Dean Buckland, the celebrated Professor of Geology in the University of Oxford, as far back as the year 1824. The Professor had observed that in the Stonesfield slate of Oxfordshire, to which allusion has already been made in the first part of this article, there were not uncommonly found teeth of the peculiar type of the one shown in woodcut 4; although many of them were of considerably larger dimension than the figured specimen. It will be seen from the figure that this type of tooth (of which only the crown or exposed portion is represented) differs very widely indeed from the teeth of the Iguanodon and Hoplosaur, of which figures were given in the preceding number of KNOWLEDGE. Thus the crown of this tooth is much flattened from side to side, with sharp cutting fore-and-aft edges, of which the front one is highly convex, while the hinder one is either nearly straight or somewhat concave. Moreover, one or both of these cutting-edges were serrated like a saw, thus indicating that these formidable teeth were adapted for tearing and rending flesh. This led Dr. Buckland to conclude that the old Stonesfield reptile, to which these teeth once belonged, must have been of carnivorous habits; and since the bones found in the same deposits indicated a creature of comparatively huge dimensions, he proposed that it should be known as the Megalosaur, or Great Reptile. Since, however, the thigh-bone of the Megalosaur does not exceed a yard in length, it is obvious that the creature was vastly inferior in point of size to the Hoplosaur and its kindred.

FIG. 4. — EDGE AND SIDE VIEWS OF THE TOOTH OF A MEGALOSAURIAN REPTILE, WITH PART OF THE SERRATIONS ENLARGED.

Similar teeth were subsequently found by Dr. Mantell in the much higher Wealden beds; and by discoveries afterwards made both in Europe and the United States, it was eventually found that the Megalosaur was merely one representative of a group of Giant Land Reptiles characterised, among other peculiarities, by the possession of teeth of the type described above, and also by having sharply curved claws adapted to aid these teeth in seizing and destroying living prey. While, therefore, the Iguanodons and the Hoplosaurs of the secondary period may be compared to the herbivorous elephants and hippopotami of the present fauna of the globe, the place of the lions and tigers of to-day was occupied in the same early epoch by the Megalosaurs.

Although these Megalosaurs walked upright, like the Iguanodons, which they also resembled in having hollow limb-bones, there is a very important difference between these two groups of reptiles in regard to that part of the skeleton which includes the haunch-bones, and is technically known as the *pelvis* (from the Latin word for a basin, in allusion to the basin-like shape of the human pelvis). Now since it is to a great extent from the structure of the pelvis that the affinity between Giant Reptiles and Birds has been proved to exist, it is worth while to pay some attention to this point; although the reader must make up his mind not to be frightened by the unavoidable use of a certain number of technical terms for bones which have no vernacular name. If, then, the reader will direct his attention to Fig. 5, which represents one side of the pelvis

FIG. 5.—LEFT SIDE OF THE PELVIS OF THE KIWI. *il*, haunch-bone or ilium; *p*, *p'*, pubis; *is*, ischium; *a*, cup for head of thigh-bone. (After Marsh.)

of the remarkable New Zealand wingless bird known as the Kiwi or Apteryx, he will observe that the haunch-bone extends as a deep vertical plate a long distance in advance of the cup for the reception of the head of the thigh-bone. He will also see that the inferior portion of the pelvis is composed of two bars of bone respectively known as the pubis and ischium, lying nearly parallel to one another and directed behind the aforesaid cup for the thigh-bone. The pubis, or more anterior bone, also gives off a small process (p') projecting towards the head of the animal from

its upper end. Now this type of pelvis is found, at the present day, only among birds, that of lizards and crocodiles being quite different. If, however, we turn to the figure of the skeleton of the Iguanodon given in the first half of this article, we shall find, as briefly mentioned there, that the pubis and ischium (seen to the right of the leg) run parallel to one another, and are directed backwards after the fashion obtaining in birds. It is true, indeed, that in the Iguanodon the pubis is shorter than the ischium; and it also gives off a large anterior plate (seen to the left of the leg) corresponding to the small process p^1 in the pelvis of the Kiwi. These, however, are but minor points of difference which do not affect the fundamental

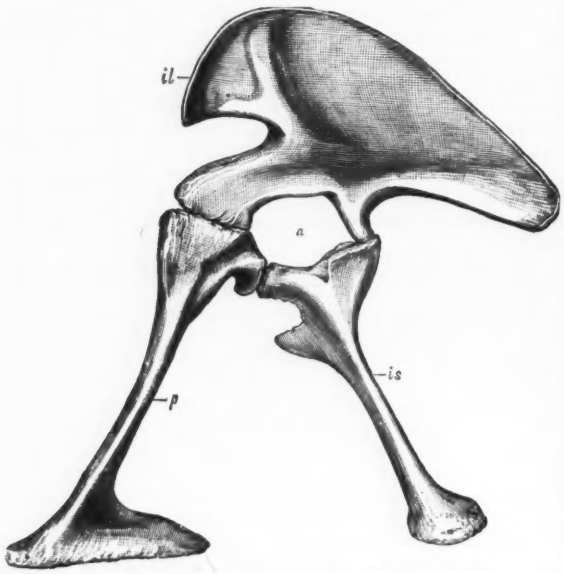


Fig. 6.—Left Side of the Pelvis of the Megalosaur. $\frac{1}{12}$th natural size. Letters as in Fig. 5. (After Marsh).

identity of plan. Again, the haunch-bone of the Iguanodon extends far in advance of the cup for the head of the thigh-bone, and thus once more follows (or, as we should rather say, leads) the bird fashion. These peculiarities in the structure of the pelvis of the Iguanodon, coupled with other features in its organisation, ought to leave no doubt, in the minds of all unprejudiced observers who hold the doctrine of evolution, that there is some direct affinity between the extinct Giant Reptiles and the modern wingless birds.

Turning now to the pelvis of the Megalosaur, of which a greatly reduced representation is given in Fig. 6, it will at once be apparent that we have to do with a widely different type of structure. Thus we notice, in the first place, that the haunch-bone extends but a comparatively short distance in front of the cup for the head of the thigh-bone. Then, again,—and this is by far the most important feature—the pubis is directed forwards instead of backwards, and thus, instead of lying parallel with the ischium, is placed at a very open angle to that bone. This form of pelvis, although differing in some details, is, indeed, of the general type of that obtaining in modern crocodiles; and thus serves to show that in this respect the Megalosaur (and likewise the Hoplosaur) were more nearly related to ordinary reptiles, and less closely to birds, than is the case with the Iguanodon.

If, however, we were led to conclude from the foregoing facts that the Megalosaur presented no closer indications of affinity with birds than is exhibited by modern crocodiles, we should be grievously in error; for not only does it exhibit such a relationship, but exhibits it in a manner which is not displayed by the Iguanodon. In this respect we have, therefore, an excellent illustration of that extreme complexity in the mutual relationships of extinct animals, which should serve as a warning against hasty conclusions as to any one extinct type having been the actual ancestor of an existing creature.

The relationship of the Megalosaur to birds is best exemplified by certain features in the form and connection of the bones of the lower leg and ankle, in attempting to explain which we must again crave the reader's pardon for the introduction of a certain number of unavoidable technicalities.

Most of us are probably aware that our own ankle consists of two rows of small bones, of which the upper row includes the heel-bone, and the ankle-bone (corresponding to the well known "huckle-bone" of a leg of mutton); while the lower row has four smaller bones. Now in moving the foot on the leg, as in the action of walking, it is evident to all of us that the joint is situated between the two long-bones of the leg and the upper row of the ankle, *i.e.* the heel-bone and ankle-bone. In a crocodile, on the contrary, the ankle joint occurs between the upper and the lower rows of the ankle, so that the heel-bone and the ankle-bone move with the leg-bones. In a bird there is yet one step further on this, for not only does the movable joint occur between the upper and the lower rows of the ankle, but the ankle-bone and the heel-bone are respectively united with the two long-bones of the leg, so as to form practically single bones; while the bones of the lower row of the ankle similarly unite with the long-bone supporting the toes, so as to form that single slender bone, with three pulley-like lower surfaces, with which we are all familiar in the leg of a fowl. An adult bird, therefore, while having an ankle-joint, has no separate ankle-bone.* In a young bird, however, as we may see for ourselves in the case of a young fowl on our dinner-table, the lower end of the so-called "drumstick," or main bone of the leg, is incompletely united to the bone itself, so that it can be readily detached; this detachable portion being, in fact, the bird's true ankle-bone.

Fig. 7.—The Lower End of the Leg-bone of the Megalosaur, with the Ankle-bone attached to it. (After Gaudry.)

Now in the crocodile, as we have already mentioned, the ankle-bone, although moving with the leg-bone, remains perfectly separate therefrom; but in the Megalosaur we find a condition exactly intermediate between that obtaining in the crocodile and the adult bird. This will be apparent from Fig. 7, where we see the lower end of the leg-bone of the Megalosaur with the ankle-bone closely applied to it, and probably immovably united thereto during life by cartilage. This condition is, indeed, precisely similar to that which exists in the young fowl; and thus we have, so to speak, displayed before us the actual manner in which the leg of a reptile has become converted into that of a bird, the young bird carrying with it the history of its origin fully apparent to all who will but read Nature's

* The reader will be assisted in this description by turning to the figure of the bones of a bird's leg, given on page 236 of the preceding number of Knowledge.

secrets aright. When, however, we make this statement we by no means intend to imply that the Megalosaur or any of its immediate kindred were the direct ancestors of birds, but only that they were more or less closely allied to such unknown ancestral types.

There are almost equally remarkable resemblances in the structure of other parts of the leg of the Megalosaur to that of birds, but the feature indicated is amply sufficient for our present purpose.

The group of which the Megalosaur is our typical example is a large one, and contains some species with a thigh-bone upwards of a yard in length, down to tiny little creatures scarcely as large as a rabbit. These reptiles were widely spread over nearly the whole globe; their remains having been obtained from the secondary rocks of Europe, India, South Africa, North America, and even as far north as Behring Strait. Some of the smaller species, like those found in the lithographic limestones of the Continent and in the United States, probably took considerable leaps with their long hind legs, and must thus have resembled the smaller kangaroos of Australia.

Briefly summing up the result of the foregoing observations, we find that the Giant Land Reptiles may be divided into three great primary groups presenting the following distinctive features. In the first group, as represented by the Iguanodon, the teeth were adapted for grinding, and had flattened crowns, ornamented with ridges on the outer side; the limb-bones were hollow; the pelvis was bird-like; and the mode of progression was bipedal. In the second group, as exemplified by the Hoplosaur, we have nearly or quite the largest known land animals; their teeth were spoon-like, and adapted for vegetable food; the limb-bones were solid throughout; the pelvis was not very unlike that of a crocodile; and the mode of progression was quadrupedal. Finally, in the third group, of which we took the Megalosaur as our type, the teeth and claws were adapted for capturing and devouring living prey; and although the pelvis approximated to the crocodilian plan, yet in the structure of the leg and ankle these reptiles (in which the limb-bones were hollow) made a closer approximation to birds than is presented even by the Iguanodon.

The above-mentioned remarkable variations of structure presented by the members of the three foregoing groups might well have been supposed to exhaust the peculiarities displayed by the Giant Land Reptiles. In the very topmost beds of the secondary rocks of the United States there occur, however, the remains of another group of these creatures, which appear to indicate a special modification of the original stock from which the Iguanodons took their origin, and which present some of the most bizarre and strange creatures yet revealed to our astonished gaze in a country where fossil animals appear to have run riot as regards strangeness. The occurrence of these creatures in the topmost cretaceous rocks, at a period just before the whole group of Giant Reptiles became extinct for ever, is like the final "flare-up" at the close of a display of fireworks, and suggests to us that the extreme specialisation to which these creatures had finally attained rendered them unsuitable for the wear and tear of life, and thus conduced to their final extinction.

The reptiles forming this group or sub-group are collectively known as the Armoured and the Horned Dinosaurs. Their pelvis is a modification of that of the Iguanodon, usually exhibiting the backward direction of the pubis and ischium; but the limb-bones were solid, and either the body was covered with huge bony plates and spines, or long horn-cores, like those of the oxen, were present on the skull.

The Armoured Dinosaurs were first made known to us by more or less imperfect skeletons discovered in the Lias, Kimeridge Clay, and Wealden formations of England. One of the best known of these reptiles is the so-called Stegosaur, of which a considerable portion of the skeleton was found some years ago in digging a well in the Kimeridge clay at Swindon; this specimen being now preserved in the British Natural History Museum at South Kensington. The back of this creature was protected by a number of large spines, but the skull (as is shown by nearly entire skeletons obtained from the Jurassic rocks of the United States) was devoid of horns, and distantly resembled that of the Iguanodon, although more depressed. The teeth of these reptiles resembled the specimen shown in Fig. 8, and were simpler and relatively smaller than those of the Iguanodon, although constructed on the same fundamental plan. This diminution in the size of the teeth, we may observe in passing, appears to be an instance of that tendency to a reduction or disappearance of the teeth in the specialised forms of many groups of animals to which we have alluded in an earlier article.

FIG. 8. — SIDE VIEW OF THE TOOTH OF AN ARMED DINOSAUR. Enlarged. (After Marsh.)

The Armoured Dinosaurs were also well represented in the Wealden (where they were first discovered by Dr. Mantell), although we have at present no evidence as to the nature of their skulls. One of these Wealden reptiles, which has been named the Hylæosaur (from the Greek *hulé*, "wood," in allusion to the Wealden, or wooded country), carried a formidable row of large flattened spines forming a crest down the back. The other, termed *Polyacanthus* (many-spined), is remarkable for having had the whole region of the loins and haunches protected by a continuous sheet of bony plate-armour, rising into knobs and spines, after the fashion of the carapace of those extinct armadillos known as Glyptodonts.*

The earliest evidence of the existence of the Horned Dinosaurs occurs in the greensand of Austria, but the specimens hitherto obtained from these deposits are too imperfect to give us any definite insight into the organisation of these reptiles. We accordingly turn to the upmost cretaceous rocks of the United States, where the remains which have been unearthed must excite the envy of all European palæontologists.

As their name implies, one of the most striking features in the organisation of these uncouth monsters is the presence of large horn-cores on the skull, as shown in Fig. 9. The skull of which we give a figure is remarkable not only for its gigantic size—the length of the figured specimen, which is said to indicate an immature individual, being about six feet—but also for its peculiar armature and structure. An imperfect skull of another species exceeds these dimensions, huge as they are, and is estimated when entire to have had a length of over eight feet. No other known animals, except whales, have a skull making any approach to these dimensions; that of the huge Atlantosaur being very small in comparison with the bulk of its owner. The skull before us is likewise remarkable for its wedge-like form when viewed from above, and carries a pair of large horn-cores immediately over the eyes, and a short and single core above the nose. During life it may be inferred with a high degree of probability that these bony cores were sheathed with horn,

* See the article on Mail-Clad Animals in KNOWLEDGE for November 1889.

like those of oxen, and that they proved equally effective weapons of defence.

The structure of the teeth is somewhat similar to that obtaining in the Iguanodon, but each tooth has two distinct roots. As in the latter, the extremity of the lower jaw is devoid of teeth, and likewise has a separate terminal bone. The upper jaw is, however, quite peculiar in having a distinct toothless bone at the extremity of the muzzle; so that it would seem probable that the mouth of these reptiles formed a kind of beak sheathed in horn like that of a tortoise. In young individuals the front horn-core is a separate ossification, but in the adult it became firmly united to the underlying bones, so that in this respect we have a precise analogy with the horn-cores of the giraffe. The brain of the creature is very minute—relatively

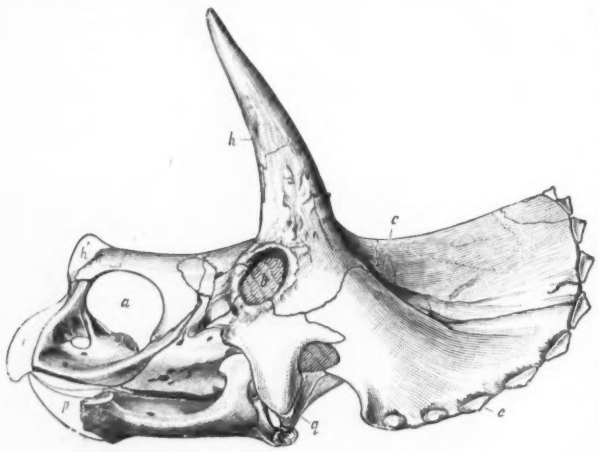


Fig. 9.—Side View of the Skull of a Horned Dinosaur. $\frac{1}{20}$ nat. size. *a*, nostril; *b*, eye; *hh'*, horn-cores; *r*, upper part of beak; *p*, lower part of beak. (After Marsh.)

smaller, indeed, than in any known Vertebrate; this, however, might have been expected from the diminutive size of the brain in other Dinosaurs, since, in the same groups, large animals always have relatively smaller brains than their smaller allies.

The pelvis of the Horned Dinosaurs is quite unlike that of any members of the group; the pubis being constructed on the plan of that of the Iguanodon, but with the loss of the bar running backwards parallel with the ischium. It thus results that the pubis is represented only by an exaggeration of the process marked *p*. in the pelvis of the Kiwi; this process occupying the same portion as the pubis of the Megalosaur (Fig. 6), but not corresponding to it, since that pubis represents the backwardly-directed bar of the pubis of the Iguanodon. This assumption of the same function and position by a totally different bone is a very remarkable, although not an unique feature, and indicates the extreme specialisation of its owner.

With this brief reference to the Horned Dinosaurs, we close our survey of the Giant Land Reptiles. In a short sketch like the present it is, of course, quite impossible to do more than glance at a few of the more striking features of the organisation of these most extraordinary creatures. The reader who has followed us throughout will, however, have acquired some general idea of their chief peculiarities and affinities; and he may profitably endeavour to realise in his mind's eye the aspect of a world in which the land-surface was peopled by these uncouth reptiles, of all shapes and sizes, while the air was tenanted by the weird Flying Dragons, of which we have treated in a previous article.

THE BREATHING ORGANS OF PLANTS.

By J. Pentland Smith, M.A., B.Sc.

VEGETABLE organisms are composed originally of one or more small spherical sacs called *cells*. Each sac consists of a living mass of protoplasm (πρωτος, first and πλασμα, form), or first formed material, which has surrounded itself with a wall of cellulose, a substance of like composition to starch, but which differs from starch in many important respects. The primordial cells of the higher plants undergo many modifications, which accord with the functions they have to perform; division of labour induces change of form. Not the least interesting of the modifications which they exhibit are those which culminate in the production of the breathing organs which form the subject of this paper.

Scattered over the surface of all land plants are numerous minute apertures, which, from the power they possess of opening and closing, are termed *stomata* (στομα, a mouth). Not only do they occur on the leaves, the chief assimilating organs of plants, but they appear in greater or less numbers on young stems and on the parts of the flower, and may even be developed on the young underground stem or tuber of the potato.* In fact, the only portion of the plant on which stomata are not found is the root; the reason of this will soon appear sufficiently obvious.

If the outer layer of skin, or *epidermis* (ἐπι, upon, and δερμα, the skin), be peeled from off the underside of a leaf, and placed in a drop of water on a glass slide, with a cover-slip laid over it, and then examined under a moderately high power with a microscope, it will be found to be pierced here and there with apertures large and small, the size of which is determined by the species of plant from which the epidermis has been derived. But a much simpler method of proving the existence of these openings in the skin-like structure is to place the cut end in water, and to blow into the blade which has been inserted in the mouth. Bubbles of gas will then appear at the cut end, and will rise to the surface of the water.

Illustrations of the lower epidermis of the leaves of five species of plants treated as described above are shown in Fig. 2, *a*, *b*, *c*, *d*, *e*; their names are as follows: *a*, Hoya; *b*, Scolopendrium vulgare, the hart's tongue fern; *c*, Lilium candidum, the white lily so much in request at the present time in floral decorations; *d*, the cabbage, Brassica oleracea, var.; *e*, Iris.

From calculations based on measurements made on 150 different plants, the German botanist, A. Weiss, found that the length of these stomata varied from ·016 to ·076 millimetres, the breadth from ·016 to ·079 millimetres, and the area from ·00011 to ·0049 millimetres. Substituting the British for the decimal system, we find that the so-called breathing organs of plants exhibit lengths varying approximately from $\frac{1}{1562}$ to $\frac{1}{315}$ inches, lengths of from $\frac{1}{1562}$ to $\frac{1}{312}$ inches, and superficial areas from $\frac{1}{6250000}$ to $\frac{1}{1250000}$ inches. They are found in millions on the surface of plants; as many as one hundred to two hundred are common numbers to find on one square millimetre of

* The potato, a staple article of diet, is a fleshily thickened underground *stem*, whose cells are packed full of starch, and whose *eyes* are dormant buds. It is these buds which develop later on into the potato stem which appears above ground

the under surface of leaves. By a comparison of the diagrams of Fig. 1 with those of Figs. 2 and 3 a tolerably correct idea of the structure of the ordinary stoma may be obtained. In each case *two cells*, termed the *guard-cells*, surround the stoma; and these are contiguous at each end of the slit. The whole apparatus is elliptical in outline, and the longer axis of the ellipse generally assumes the same direction as that of the structure on which the stoma arises. Each of the stomata depicted in the figures has arisen by a splitting of a cell of the epidermis; but nevertheless they differ in many important respects from the cells which surround them, and also exhibit differences among themselves chiefly as regards their relative positions. In the first place it is plainly evident that, with the exception of the Fern (Scolopendrium vulgare), chlorophyll or green-colouring matter is absent from all the epidermal cells except the guard-cells, which are densely packed with chlorophyll granules. In the second place, the walls of the guard-cells exhibit a difference in thickness, those portions next the apertures, and those contiguous to the

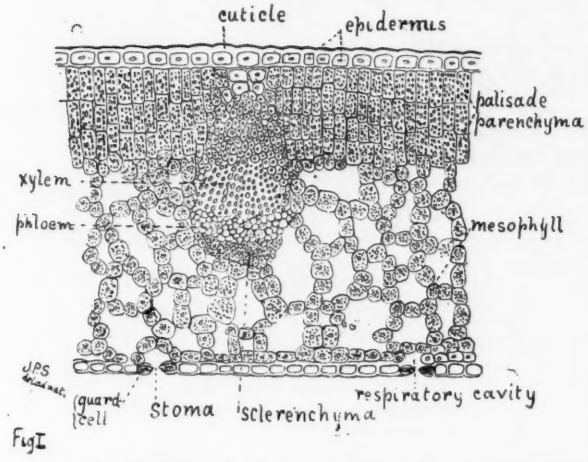


FIG. 1.—TRANSVERSE SECTION OF THE LEAF OF *Osmanthus*. The cuticle is the continuous outer coat of the epidermal cells. The *xylem* (ξυλον, wood) is the technical name applied to the wood, the tissue which is the chief conductor of the sap up the stem. *Phloem* (φλέω, to overflow) is the tissue which carries down the elaborated sap. *Sclerenchyma* (σκληρος, hard) is thick-walled supporting tissue. The *mesophyll* (μεσος, middle; and φυλλον, a leaf) is the tissue which occupies the middle of the leaf: it consists of a loosely arranged tissue with many air-spaces amongst the cells.

epidermal cells which may be termed the lateral walls, are very thin; while, on the other hand, the walls facing the outside of the leaf, and in part lining the respiratory cavity, have become much thickened. Furthermore, the position of the whole stomatal apparatus is subject to variation. In the Crassula and White Lily (Fig. 3, *a*, *c*) the guard-cells are almost on a level with the other epidermal cells, whereas in the Iris and Horse-tail (Fig. 3, *b*, *d*) they are in the one case half, and in the other wholly, surmounted by these cells. The two lateral adjacent cells of the epidermis in the case of the Sedum form part of the stomatal apparatus; they are termed the *subsidiary cells of the stoma*. The stomata of Nerium, the Oleander, and a climbing plant common in our greenhouses, occupy a peculiar position. On the surface of the leaves are numerous pits; each of these is half filled with hair-like appendages, projections of the cells lining the pit, and at the base are situated the stomata, two, three, or more in number. In all cases the stomata open into an intercellular space, the so-called "respiratory cavity," which is enclosed by thin-walled cells containing chlorophyll. Figure 2 and its description give fuller information on the stomatal surroundings. There are many anomalous forms of stomata, which the reader can easily find out for himself by adopting the simple methods described in the footnote.*

With these we will not at present deal, but will proceed to discuss the mechanism of the stomata and the use of the stomata to the plant.

The mechanism of the stomata is a subject which has received the attention of many botanists, but no satisfactory solution of the problem has yet come to hand. The following may be taken as a general statement of the present views on the case. In the guard-cells are many granules of the green colouring matter, chlorophyll. The presence of these induces during daylight carbon assimilation. In other words, in these, as well as in the other chlorophyll-bearing cells, the carbon dioxide of the air, commonly but wrongly spoken of as carbonic acid gas, is decomposed into its constituent elements—carbon and oxygen. The carbon and part of the oxygen are retained by the cells, and the rest of the oxygen is given out again to the atmosphere. The carbon and oxygen then unite with water which is present in the cells. The using up of this water causes a fresh supply to be drawn in from the surrounding cells. This supply probably comes, in the case of the guard-cells, from the surrounding epidermal cells, and the process goes on continuously during sunlight, so that the guard-cells are during that period always kept filled with a watery fluid, and thus rendered turgid. Turgidity causes a straightening of the thin lateral walls of the guard-cells, and a simultaneous curving of each of these cells in such a manner as to open the orifice. On the other hand, when the guard-cells become flaccid, as they do at night, the orifice is closed.

A few general remarks on vegetable physiology form a necessary introduction to a discussion on the function of the stomata. As we stated above, protoplasm is the essential portion of the plant; it is the vital substance by whose activity all the other portions of the organism are built up. Its composition is extremely complex; no chemical formula can be assigned to it, but it is known that the elements carbon, hydrogen, oxygen, nitrogen,

* As many of our readers are doubtless the possessors of a microscope, perhaps the following hints on the preparation of slides for microscopic use will be appreciated. If it be wished to make an examination of the epidermis of the leaf, the leaf should be steeped for some time in water and then folded round the fore finger of the left-hand. The operator can then peel off a portion of the epidermis by inserting a needle mounted in a handle into the leaf near the thickest vein or midrib, and then working gently under the epidermis in a direction away from the midrib. To obtain a cross or transverse section, that is one at right angles to the blade of the leaf, requires more skill and practice. A part of the leaf should be placed in a slit made in a piece of carrot or pith, and then with a very *sharp* hollow ground razor, thin sections of both carrot and leaf should be cut off. The razor should not be forced right across the object, but should be worked with a sliding motion from heel to tip. Both the object and the razor must be kept wet with dilute methylated spirit. The sections obtained should be transferred to a watch-glass containing water and methylated spirit, and then the thinnest of these having been selected, they can be permanently mounted by placing them, one in each case, by means of a camel-hair brush, on a glass slide measuring 3 inches by 1 inch. The superfluous water must now be drained off with a piece of blotting-paper; then some glycerine jelly must be gently lowered on the section with a glass rod. The whole must then be covered with a thin glass cover-slip of $\frac{3}{4}$-inch diameter. The epidermis may be mounted in the same manner.

N.B.—The needles in handles, glycerine jelly, slides, and cover-glasses, can all be obtained from any dealer in microscopical appliances. They are quite inexpensive. The glycerine jelly requires to be heated before use.

sulphur, and probably phosphorus, enter into its constitution. That a plant may be able to elaborate its protoplasmic material, it must be supplied with those elements. They have for this reason been termed the *essential elements* of plant food. But in addition to these the presence of potassium, magnesium, and iron has been found necessary for the healthy and vigorous development of the plant. The question now arises, From what sources does the plant obtain these elements? The answer is, From

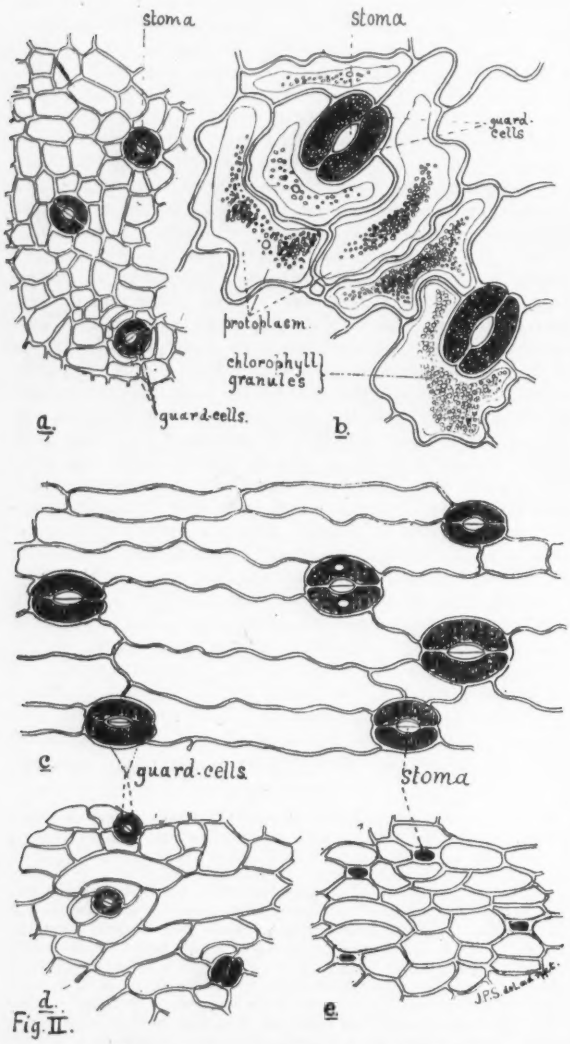


Fig. 2.—Epidermis of—*a*, Hoya; *b*, Scolopendrium vulgare: *c*, Lilium candidum; *d*, Brassica oleracea, Cabbage; *e*, Iris.

the soil and from the air. The air furnishes it with carbon and oxygen; the other elements are derived from the soil. The mode of obtaining carbon and oxygen we have just described; but, besides, in the air there is a great quantity—$\frac{1}{5}$th part by volume—of free oxygen, so that for the purpose of respiration the plant can obtain it, so to speak, ready-made. It seems very strange, but still the statement is supported by numerous experiments, that although there is as much as 80 per cent. of free nitrogen in the atmosphere, plants do not make use of it, in preference taking it in the combined forms from the soil. The organs which are the absorbents of carbon and oxygen are the leaves, and also the stem when it contains green colouring matter; while by means of numerous hairs, which are developed at a little distance behind their growing point, the young roots absorb the nutrient material from the soil. Before a substance can pass into a plant it must be in solution in water; this applies to gases as well as to solids. The soluble salts of the soil are present there in very dilute solutions, and it is only as such that the plant is capable of receiving them. Taking into consideration the exceedingly dilute state in which the salts are absorbed, and the large quantity of the elements which compose them required by the plant to enable it not only to increase in size, but even to live, it will be seen

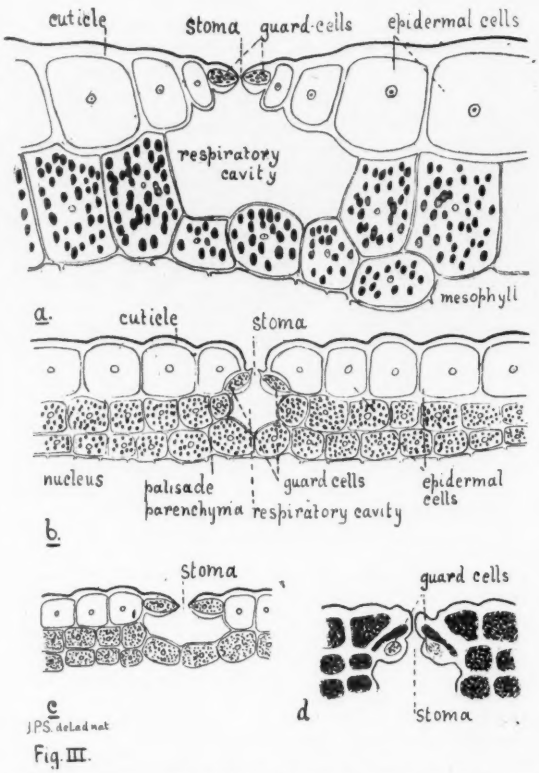


Fig. 3.—*a*, Transverse section of stomatal apparatus of Crassula napus; *b*, Iris; *c*, Lilium candidum, White Lily; *d*, Equisetum arvense, Horse-tail.

that a great volume of liquid must be taken in by the roots of plants. The absorbed liquid forms what is generally termed the *sap*. It travels up the stem chiefly by way of the wood to the chlorophyll-bearing cells, where it unites with the carbon and oxygen obtained by these cells from the air. Only a very small quantity, however, of the absorbed water is required by the plant. The superfluous water must be given off to promote fresh absorption by the roots. This giving off of water is termed *transpiration*, and it is the function of the stomata to regulate this process. The most active transpiration takes place when the stomata are open, and it is also at this period that carbon assimilation is proceeding with the greatest vigour. The two processes are thus closely connected the one with the other, and the mechanism of the stomata is wonderfully

adapted to subserve the requirements of both. The stomata are then, properly speaking, the *transpiring organs* of plants. How is it they have acquired that name which has furnished the heading to this article? Although all plants which contain chlorophyll inhale during sunlight carbon dioxide and exhale oxygen, they nevertheless exhibit a phenomenon the antithesis of this, namely, that of respiration, the inhalation of oxygen and exhalation of carbon dioxide, processes identical with those which take place when an animal breathes. And just as in an animal breathing must go on continuously during its life, so the phenomenon of respiration is a continuous one in plants, differing in this respect from the intermittent process of carbon assimilation. The latter is so much in excess of the former, however, during bright sunlight as almost to completely obscure it. It is doubtless the case that the carbon dioxide and oxygen which are absorbed by a plant go in chiefly by way of the leaves, but that the stomata are of especial importance in this connection is open to doubt; in fact, Boussingault has proved that the leaves of the Poplar, Chestnut, Peach, &c., absorb carbon dioxide more readily by their upper than by their under surfaces, although stomata are more numerous on the latter than on the former. Unquestionably they afford means of exit to carbon dioxide during respiration, and to oxygen during carbon assimilation; but the regulation of transpiration, or exhalation of watery vapour, is the true function of those organs which were held by the old botanists to be all important in respiration, and hence named by them the breathing organs of plants.

COLOURED STARS.

By J. E. Gore, F.R.A.S.

On a clear night a careful observer will notice a marked difference in the colours of the brighter stars. The brilliant white or bluish white light of Sirius, Rigel, and Vega contrasts strongly with the yellowish colour of Capella, the deeper yellow or orange of Arcturus, and the ruddy light of Aldebaran and Betelgeuse. These colours are, however, limited to various shades of yellow and red. No star of a *decided* blue or green colour is known, at least among those visible to the naked eye in the Northern Hemisphere. The third magnitude star Beta Libræ is described by Webb as of a "beautiful pale green hue"; but probably such a tint in the light of this star will to most people prove quite imperceptible. Dr. Gould, observing it in the Southern Hemisphere, says: "There is a decidedly greenish tinge to the light of β Libræ, although its colour cannot properly be called conspicuous."

Among the ruddy stars visible to the naked eye, Herschel's "garnet star" Mu Cephei is generally admitted to be the reddest, but it is not sufficiently bright to enable its colour to be well distinguished without the aid of an opera-glass. With such an instrument, however, its reddish hue is striking and beautiful, and very remarkable when compared with other stars in its vicinity. Like so many of the red stars, Mu Cephei is variable in its light; but it seems to have no regular period, and often remains for many weeks without perceptible change. It may be seen near the zenith in the early evening hours, towards the end of October, and in this position its curious colour is very conspicuous. Among the brightest stars Betelgeuse is perhaps the reddest; and the contrast between its ruddy tint and the white colour of Rigel, in the same constellation, is very noticeable. Like Mu Cephei, Betelgeuse is irregularly variable in its light, but not to such an extent, and, like the "garnet star," it frequently remains for lengthened periods nearly constant in brightness. There are other cases of reddish colour among the naked-eye stars. Among these may be noted Antares, Alphard (Alpha Hydræ), noted as red by the Persian astronomer Al-Sufi, in the 10th century, and called by the Chinese "The Red Bird"; Eta and Mu Geminorum, Mu and Nu Ursæ Majoris, Delta and Lambda Draconis, Beta Ophiuchi, Gamma Aquilæ, &c., and others in the Southern Hemisphere.

But it is among the stars below the limit of naked-eye vision that we meet with the finest examples of the red stars. Some of these are truly wonderful objects. The small star No. 592 of Birmingham's Catalogue of Red Stars (No. 713 of Espin's edition), which lies a little south of the 5½ magnitude star 79 Cygni, was described as "splendid red" by Birmingham; "very deep red" by Copeland and Dryer; and "orange vermilion" by Franks. The star Birmingham 248, which lies about 5 degrees south of Nu Hydræ, is another fine specimen, Birmingham described it as "fine red" and "ruby"; Copeland as "brown-red"; Dreyer as "copper-red"; and Espin as "magnificent blood-red."* This star is variable in light, as the estimates of magnitude range from 6·7 to below 9. About 3 degrees to the north-east of this remarkable object is another highly-coloured star, known as R. Crateris. It is readily found, as it lies in the same telescopic field of view with Alpha Crateris, a 4½ magnitude star. Sir John Herschel described it as "scarlet, almost blood-colour; a most intense and curious colour." Birmingham called it "crimson," and Webb "very intense ruby." Observing it with a 3-inch refractor in the Punjab in 1875, I noted it as "full scarlet." It varies in light from above 8th to below 9th magnitude, and has near it a star of the 9th magnitude of a pale blue tint.

Another very red star is No. 4 of Birmingham's Catalogue, which will be found about 5 degrees north preceding the great nebula in Andromeda. It is of about the 8th magnitude, and may be well seen with a 3-inch telescope. Krüger describes it as "intensiv roth," Birmingham as "fine red" and "crimson," Franks as "fine colour, almost vermilion," and Espin as "intense red colour, most wonderful."

Another fine object is R. Leporis, which forms roughly an equilateral triangle with Kappa and Mu Leporis. This also is variable from 6½ to 8½ magnitude. It was discovered by Mr. Hind in 1845, and described by him as "of the most intense crimson, resembling a blood-drop on the background of the sky; as regards depth of colour, no other star visible in these latitudes could be compared with it." Schönfeld calls it "intensiv blutroth"; but Dunér, observing its spectrum in 1880, gives its colour as a less intense red than that of other stars. Possibly it may vary in colour as well as in light.

The variable star U. Cygni, which lies between Omicron and Omega Cygni, is also very red. Webb described it as showing "one of the loveliest hues in the sky." It varies from about 7 to 11½ magnitude with a period of about 461 days.

Another deeply-coloured star is the well-known variable

* The colour sensations produced by the light of the same star in the eyes of different observers probably differ, and the words they select to describe and compare such colours differ more widely still. To my eye no star in the heavens appears nearly as red as the light from a railway-signal or the port-light of a ship. The light of such stars appears to my eyes as decidedly reddish, but not so red as the sparks from a locomotive as they die out, while the light from Vega appears to me decidedly bluish. Prof. Pickering's spectroscopic survey of the heavens will afford us a much more definite and satisfactory means of judging as to changes in the quality of the light of stars than we have hitherto possessed.—A. C. R.

R. Leonis. Hind says:—"It is one of the most fiery-looking variables on our list—fiery in every stage from maximum to minimum, and is really a fine telescopic object in a dark sky about the time of greatest brilliancy, when its colour forms a striking contrast with the steady white light of the 6 mag. a little to the north." This latter star is 19 Leonis.

In the Southern Hemisphere there are some fine examples of red stars. Epsilon Crucis, one of the stars of the Southern Cross, is very red. Mu Muscæ is described by Dr. Gould as of "an intense orange-red." Delta[2] Gruis is a very reddish star of about the 4th magnitude. Pi[1] Gruis was observed by Gould as "deep crimson," and forming a striking contrast with its neighbour, Pi[2] Gruis, which he notes as "conspicuously white." The variable L_2 Puppis is described as "red in all its stages, and remarkably so when faint." Miss Clarke observing (at the Cape of Good Hope) R. Doradûs, another southern variable, says:—"This extraordinary object strikes the eye with the glare of a stormy sunset," * and with reference to the variable R Sculptoris, described by Gould as "an intense scarlet," she says:—"The star glows like a live coal in the field," a description I have found very applicable to other small red stars.

An 8th magnitude star about 5 degrees north of Beta Pictoris is noted by Sir John Herschel in his "Cape Observations" as "vivid sanguine red, like a blood drop. A superb specimen of its class." With reference to a star about 8½ magnitude in the field with Beta Crucis, Herschel says:—"The fullest and deepest maroon red; the most intense blood red of any star I have seen. It is like a drop of blood when contrasted with the whiteness of Beta Crucis."

Of stars of other colours the asserted green tint of Beta Libræ has already been referred to. Among the brighter stars of the Southern hemisphere Theta Eridani, Epsilon Pavonis, Nu Puppis, and Gamma Tucanæ are said to be decidedly blue. The wonderful cluster surrounding the star Kappa Crucis contains several bluish, greenish, and red stars, and is described by Sir John Herschel as resembling "a superb piece of fancy jewellery."

Among the double stars we find many examples of coloured suns. Of these may be mentioned Epsilon Boötis, of which the colours are "most beautiful yellow, superb blue," according to Secchi; Beta Cephei, "yellow and violet"; Beta Cygni, "golden yellow and smalt blue"; Gamma Delphini, of which I noted the colours in 1874 as "reddish yellow and greyish lilac"; Alpha Herculis, "orange and emerald or bluish green," and described by Admiral Smyth as a "lovely object, one of the finest in the heavens"; Zeta Lyræ, "pale yellow and lilac" (Franks), and Beta Piscis Australis, of which I observed the colours in India as white and reddish lilac.

Some distant telescopic companions to red stars have been described as blue. This may in some cases be due, partly at least, to the effect of contrast. In others, the blue colour seems to be real. This has been shown spectroscopically to be the case with the bluish companion of Beta Cygni.

The physical cause of the difference in the colour of stars is still more or less a matter of mystery. Although we cannot consider it proved that the red stars are cooling and "dying out" suns, as has been suggested, we may, I think, conclude that their temperature, although doubtless very high, must be lower than that of the white stars. We know that a bar of iron when heated to redness is not so hot as when raised to a "white" heat; and although the analogy between hot iron and stellar photospheres may not be a perfect one, it seems probable that the higher the temperature of a star the whiter will be its colour. Most of the white stars, as Sirius, Vega, and those only yellow or slightly coloured, show spectra of Secchi's first and second type, while the great majority of the red stars exhibit banded spectra of the 3rd and 4th types.

To this rule there are, however, like other rules, some notable exceptions. For instance, Aldebaran, Alpha Hydræ, Xi Cygni, and 31 Orionis, although distinctly reddish stars, show well-marked spectra of the 2nd or solar type. On the other hand, Rho Ursæ Majoris and Omega Virginis, which, according to Dunér, are only slightly yellow, have well-marked spectra of the 3rd type.

An apparent change of colour seems in some cases to be well established. The supposed red colour of Sirius in ancient times is well known, but that such a remarkable change of colour has really taken place in this now brilliantly white star is very far from being established. It seems more probable that the idea of change is due to the mistranslation of a word applied to the star by some of the ancient writers, a word which probably referred to its brightness, not to its colour. A certainly established change is, however, found in the case of the famous variable star Algol, which is distinctly described as red by Al-Sufi in the tenth century. It is now pure white, and this is probably the best attested instance on record of change of colour in a bright star.

Schmidt's Nova Cygni of 1876 was noted as "golden yellow" on the night of its discovery. When it had faded to about the 8th magnitude, Dr. Copeland called it "decided red"; but when examined at Lord Crawford's Observatory in September 1877, its colour was recorded as "faint blue"! The new star in the Andromeda nebula was considered to be yellowish or reddish by most observers when near its maximum; but about a month later its colour was noted as "bluish." Possibly, however, these *Novæ* may be really nebulæ and not stars at all.

Among the red and variable stars there are many suspected cases of colour variation. Espin and other observers have noted that the wonderful variable Mira Ceti is much less red at maximum than at minimum. My own observations confirm this. When at its maximum brightness Mira does not seem to me a very highly-coloured star, while at one of the minima I noted it as "fiery red." Possibly, however, the great difference between its maximum and minimum brilliancy may have an influence on estimations of its colour. The remarkable variable Chi Cygni is said to be "strikingly variable in colour." Espin's observations in different years show it "sometimes quite red, at others only pale orange red." The star Birmingham 118 was described by Schjellerup in 1863 as "decided red," but was found yellow by Secchi in 1868, "bluish" by Birmingham, 1873–1876, "no longer red" by Schjellerup in March 1876, and "white" by Franks in 1885. Birmingham 169 was found red by Struve, blue or bluish white by Birmingham in 1874, and white at Greenwich in the same year. Espin also saw it white in March 1888. The star Birmingham 30, which lies close to Phi Persii (54 Andromedæ), was described by Schweizer as "etoile rouge presentant un petit disque" in Jan. 1843; Birmingham noted it "light red" in December 1875; Copeland "deep red" in Jan. 1876, and Dreyer "reddish" in September 1878; but Espin, in November and December 1887, found it "certainly not red, and nothing peculiar in the star's appearance." It might be expected that these curious changes of colour, if real, would be

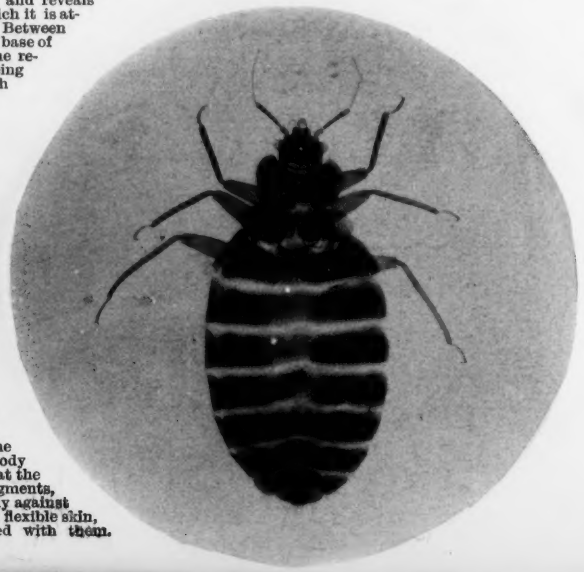
* *Observatory*, Dec. 1888.

XUM

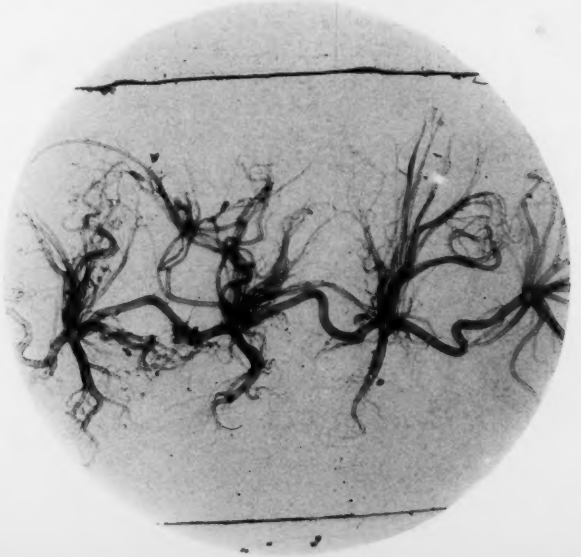
2. **WATER-BUG (Corixa)** viewed from beneath, magnified about 8 diameters. This insect lives in ponds, swimming chiefly by aid of its flattened and deeply fringed hind-legs. Owing to distortion caused by flattening the specimen for mounting, the front pair of legs, with their curious blade-like terminal joints, appear to proceed from the head; they may, however, be traced back to their origin in the prosternum. The extraordinary length of the tarsal claws in the intermediate legs will be noticed. The antennæ are, in these water-bugs, very short and concealed in depressions on the head; hence they do not appear in this specimen. The fore-wings are semi-transparent and prettily mottled with black and yellow; the division between clavus and corium is distinctly marked as a black line crossing the wing diagonally; the corium appears to shade off almost imperceptibly into the membrane at the tip of the wing. The hind-wings are extremely delicate in this genus, and it is difficult to preserve them intact in specimens mounted in balsam; in the present instance they were irretrievably damaged, and, being extremely transparent, scarcely any trace of them appears. The broad border to the abdomen is the connexivum.

4. **PORTION OF TRACHEA OF A LARGE WATER-BEETLE.** This specimen is more highly magnified than the preceding, and shows the internal structure of the tube. The cross lines are the coiled thread, which, as the specimen is very transparent, is seen in its whole course, and its apparent crossings are due to the difference of direction it takes on the upper and under surfaces, which difference, again, is largely due to flattening. In some parts smaller tubes are seen issuing from the main trunk, and the course taken by the thread under these circumstances may to some extent be made out.

1. **BED-BUG, FEMALE (Acanthia lectularia),** viewed from above, magnified about 9 diameters. In consequence of the flattening necessary for mounting as a transparent object, the abdomen is unduly elongated. The clear spaces between the segments are the parts in which the skin is not hardened by the accumulation of chitin, and these should not be visible, but the segments should appear closed up so as to make the dark parts continuous. For the same reason the head is thrust rather too far forward, and reveals the flexible skin by which it is attached to the thorax. Between the antennæ is seen the base of the rostrum or beak, the remainder of the organ being bent back underneath the head; the corneal surfaces of the eyes form two prominent swellings at the sides of the head. Immediately behind the head is the promotum or upper surface of the prothorax, with projecting sides, and behind this are the two scale-like elytra or fore-wings, a little more prominent at the sides than is natural, in consequence of the flattening. Between them lies the triangular scutellum. Inside the abdomen, a little below the middle, may be seen an egg, lying in a sloping position. The hairs which cover the body are most easily traced at the hind margins of the segments, where they show plainly against the clear background of flexible skin, which is not furnished with them.



3. **TRACHEÆ (Breathing-tubes) OF SILKWORM.** A main trunk is shown connecting four stigmata (orifices by which communication is maintained with the outer air). Round each orifice many tracheæ branch in various directions, subdividing and becoming smaller as they recede. The four stigmata would appear as oval marks down the side of the silkworm. The coiled thread inside the tracheæ, which prevents their collapse, can with difficulty be traced in this specimen, on account of the closeness of its coils.



XUM

the clear background of Heath's skies,
which is not furnished with them.

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accompanied by corresponding changes in the star's spectrum. Such may be the case, and observations in this direction would probably lead to some interesting results.

There seems to be some law governing the distribution of the coloured stars. The white stars appear to be most numerous, as a rule, in those constellations where bright stars are most abundant, for instance, in Orion, Cassiopeia, and Lyra; yellow and orange stars in large and ill-defined constellations such as Cetus, Pisces, Hydra, Virgo, &c. The very reddish stars are most numerous in or near the Milky Way, and one portion of the Galaxy—between Aquila Lyra and Cygnus—was termed by the late Mr. Birmingham "the red region in Cygnus."

THE BED-BUG.—III.

By E. A. Butler.

THE eggs of the bed-bug are small, white, oval objects (Fig. 11); they are laid in cracks and crevices, and are caused to adhere to the surface on which they are deposited by a kind of varnish with which they are wet when laid. According to Southall, about fifty eggs are laid in each batch. The young bugs make their entry into the world by pushing off a kind of lid at the end of the egg, and the empty egg-shell then looks like a little round-bottomed china jar with a neat rim round the opening. The newly-hatched bug is a very minute, transparent, six-legged creature, showing no trace of the brown colour which characterizes it in adult life. It is sufficiently transparent to reveal something of its internal economy through the skin; and after it has had a meal of blood, a dark red spot appears in the region of its digestive apparatus. It has a broad, triangular head, and the antennæ are short, and proportionately much thicker than when full-grown. Of course, no signs of wings are apparent while the insect is in this immature condition (Fig. 12).

Fig. 11.—Egg of Bed-Bug.

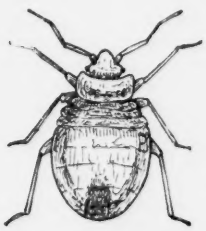

Fig. 12. Newly-hatched Bug.

During the course of the larval life the skin is shed several times, each moult being accompanied by a closer approach to the form of the adult. The operation is effected in the same way as in the cockroach, viz. by the splitting of the skin along a straight line down the middle of the back in the region of the thorax, and the whole animal gradually extricates itself at this aperture, carefully removing not merely the more robust parts of the body from their covering, but neatly withdrawing also the more slender parts, such as the legs and antennæ, each separately from its own sheath. During the moult, the claws at the tips of the tarsi are useful in obtaining a foothold on the irregularities of the wood, paper, &c., on which the change takes place; by this means the shells of the limbs are prevented from becoming crushed and collapsed, and are enabled to retain their proper forms; hence, but for the distortion caused by the fracture along the back, and the paler tint, the cast skin (Fig. 13) might easily be mistaken for the insect itself.

The last moult but one introduces the form usually called the nymph (Fig. 14), which corresponds to the chrysalis of those insects whose metamorphosis is complete. As the bug grows with each moult its colour deepens, and its skin becomes harder and less flexible, so that when it has reached the nymph stage it closely resembles the adult, though still rather smaller. The chief differences perceptible are in the region of the hinder part of the thorax and the fore part of the abdomen. The prothorax is very similar to that of the adult, the leaf-like margins projecting by the sides of the head; the next two segments, however, have not become so specialised as will ultimately be their fate, and they appear as distinct bands right across the body. The first of them, which is the mesothorax, already shows, however, a slight indication, at the sides, of the outline of the fore wings. The next three segments are very similar to one another, and no distinct line of division shows where the thorax ends and the abdomen commences. But if we remember that the thorax consists in all of only three segments, and that the first of these is the very distinctly marked prothorax, the determination of the line of junction of the chief regions of the body becomes easy.

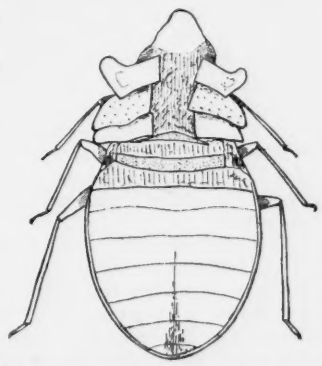

Fig. 13.—The Cast Skin of an Adult Bug, seen from above.

While in the nymph condition the bug is still just as active as before, and continues to take food with equal readiness. At length the final moult occurs, and the insect is sexually mature, and acquires its rudimentary elytra, or upper wings. No further growth takes place, as, owing to the inflexibility of the skin, this can only be effected by moulting. The food now taken, therefore, serves not for increase of bulk, but to maintain the proper balance of the activities of the body and to supply materials for the perfecting and discharge of the reproductive

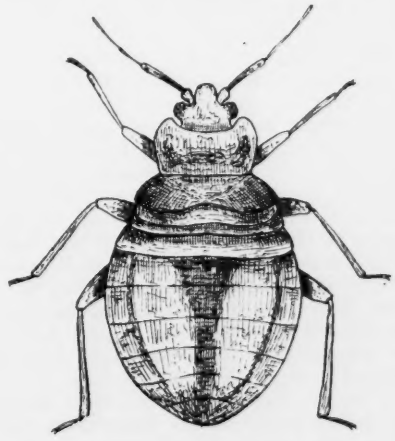

Fig. 14.—Bed-Bug at the Nymph Stage.

functions. The insect is said to require in all about eleven weeks to reach maturity, but the exact duration of its metamorphoses is no doubt greatly dependent upon the regularity and amount of the supply of food. In the adult condition it can certainly endure long fasts with impunity; De Geer kept several in a sealed bottle for more than a year without food. It is also a well-known fact that bugs sometimes absolutely swarm in houses that have for a long time been uninhabited. In such cases it is obvious that they have managed to exist without access to human blood; still it does not necessarily follow that they have been entirely without food of any kind, and when we remember that their human parasitism is probably an acquired habit, their appearance under such conditions will be less difficult to understand.

It has been supposed that they are able to abstract juices sufficient to support life from the wood-work of buildings, and if we take into consideration the absorptive properties of unpainted soft woods, such as deal, it seems far from incredible that such may be the case. That an insect which has been accustomed during the greater part of its individual life to subsist upon animal matter should suddenly change its diet and feed upon vegetable substances, or upon mere inorganic moisture, and the slight amount of organic matter that may contain in solution, would in most cases be an unprecedented proceeding, and there are hosts of insects which would rather starve than do it. But it is not at all an unusual circumstance in the order Hemiptera, and several of the wild bugs seem to be quite indifferent as to whether they are supplied with an animal or a vegetable diet. Another suggestion by which it has been proposed to account for their presence in uninhabited houses is that the colony having been established during the human occupation, they have, since the desertion of the premises by their hosts, preyed upon one another, and so sustained life. But an obvious objection to the theory is that by such a course their numbers would be speedily thinned, and the colony would probably soon become extinct, a result which by no means tallies with experience. If in such cases the bugs really found any difficulty as to the commissariat, of course migration would be open to them, and it is difficult to believe that, enterprising as they are, they would not avail themselves of such an expedient, if really hard pressed by famine.

While it may be admitted that the hard-skinned, ungrowing adults can subsist for long periods without food, it is probable that the younger and softer skinned forms, in whose bodies the vital processes are more rapid, require more frequent supplies. Such, at any rate, is the experience of those who have attempted to rear any of the wild species of Hemiptera with which our woods, fields, and hedges swarm. As the surest and safest way of avoiding bugs in the house is the cultivation of scrupulous cleanliness, it would seem probable that the miscellaneous material included under the name "dirt," which is, much of it, of organic origin, may contribute in some way to their support; but still it must be borne in mind that, owing to the peculiar structure of their mouth organs, whatever be the nature of the material from which they derive their food, only its liquid portions can be partaken of. Anyhow, there seems little doubt that human blood is not an absolute necessary of life to this disgusting parasite, and perhaps may be more correctly regarded as a luxury; and it is quite possible that before its association with mankind, *Acanthia lectularia* may have been a purely vegetable feeder, subsisting on the sap of trees. Southall declares that he fed the numerous families he kept on such food as this, using chiefly deal for the purpose. Hard woods, such as oak, walnut, and mahogany, or scented woods such as cedar, they failed to extract any nutriment from, and died if confined with these alone.

In our last paper a passing reference was made to the *Corixæ*, as exhibiting some of the most beautiful developments of hind-wings to be met with in the whole order Hemiptera. The photographs accompanying the present article give the opportunity of contrasting the fore-wing of one of these insects with the rudimentary scale-like elytron of the bed-bug, as well as of comparing it with that of the field-bug figured last month. It will be observed that there is a similar composite structure of the wing—corium, clavus, and membrane being present, though no part of the first-mentioned is divided off from the main body to form a cuneus. It is perhaps difficult to realise at first sight that insects so widely different in appearance and habitat as the *Corixa* and the Bed-bug, nevertheless belong to the same order. Though so utterly dissimilar in shape, however, the two insects are constructed on what is essentially the same type or plan, their mouth organs being almost identical in form and arrangement, and the method of their growth and development, and the cycle of changes they pass through, entirely similar. Hence we see that an insect's systematic position is to be determined, not by its habits or method of life, nor by the actual form even of its body or of many of its organs, since similarities in these respects often co-exist with profound differences in other and more important particulars; and, on the other hand, the greatest divergence in habits, form of body, and nature of limbs and antennæ, may be observed in insects that are in other and more essential respects closely alike. Attention should therefore be paid specially to three points in determining the systematic position of any insect, viz. the nature of its mouth organs, the structure of its wings, and the kind of metamorphoses it passes through; insects which are alike in these respects may be regarded as intimately related to one another, and as referable to the same order, however they may differ in other ways.

Like all other insects, bugs, of course, breathe by inhaling air, not at the mouth, but at certain openings in other parts of the body, whence it is passed along delicate tubes (*tracheæ*) to all parts of the system. The stigmata, or openings to the tracheæ, are in the present instance extremely small, and therefore not easy to trace. They are situated on the under surface of the abdomen, not far from the edge of the body. Perhaps the best way to see them is to remove the chitinous band which forms the boundary of any of the central abdominal segments on the under side, and, after relieving it of any adhering viscera, to examine it with the compound microscope. A low power will be sufficient to show the stigmata, one on each side, as minute roundish openings surrounded by a rim-like lip. From these pass the main tracheal trunks, the branches of which, like tiny threads of silver, run hither and thither over the body. Their silvery appearance is due to the air they contain. The body of the living or freshly-killed bug is usually sufficiently transparent for some of the chief branches to be traced from the outside.

The accompanying photographs show the corresponding organs of a water-beetle and a silkworm, and will serve to indicate, more clearly than any verbal description can do, the sort of thing that is to be looked for in a dissection. The structural details cannot be properly made out till the tubes are removed from the surrounding organs and freed from the air they contain. The fine thread which projects round their inner walls prevents collapse; and so well does it perform its function that even in the dead and dried bodies of bugs, however ancient, such as

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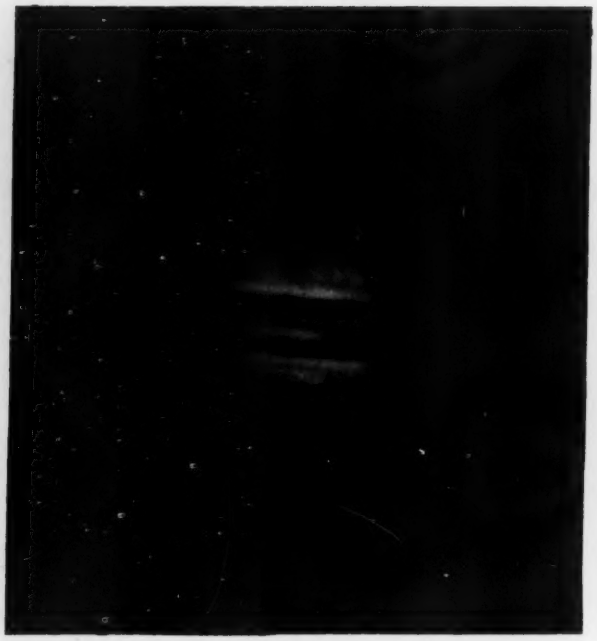
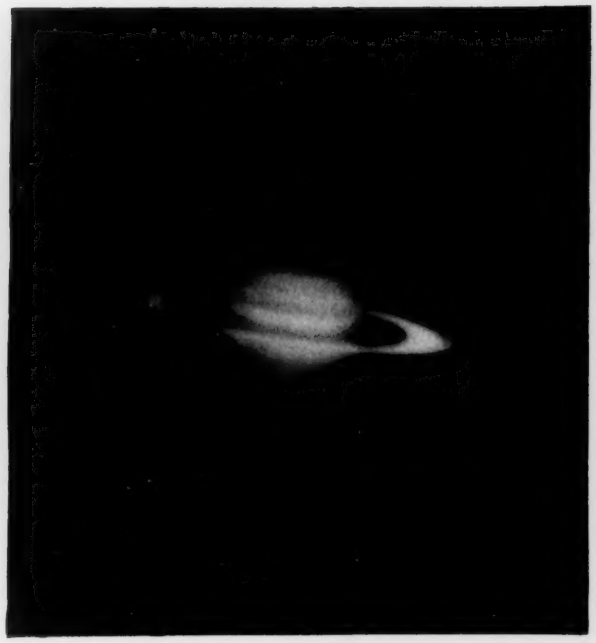


Photograph of the Planet Jupiter.

Taken by Prof. W. H. PICKERING, with an exposure of 87 seconds, and telescope of 13 inches aperture. 1889, July, 12d. 19h. 38m.



Photograph of the Planet Saturn.

Taken by Prof. W. H. PICKERING, with an exposure of 6m. 16s., and telescope of 13 inches aperture. 1889, February, 7d. 18h. 54m., G.M.T.

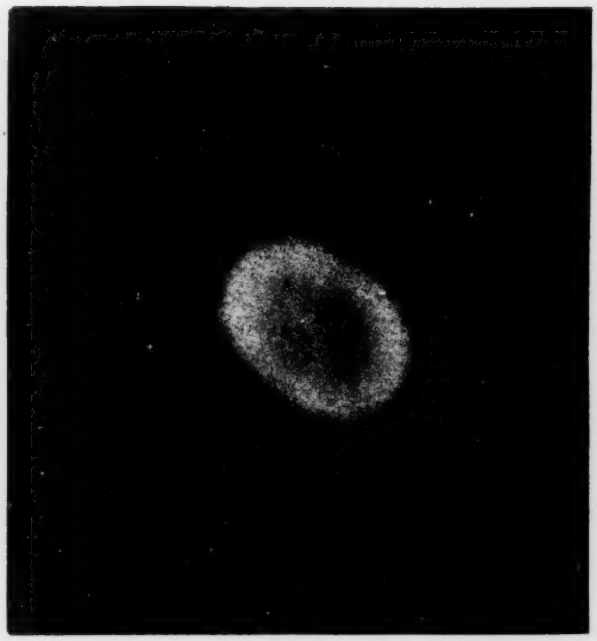
N.

E.

Annular Nebula in Lyra R.A. 18h. 48m. N.P.D. 57° 8′.

From a photograph taken by M. TRÉPIED, at the Algiers Observatory, with six hours exposure.

N.



W.

Mr. Lassell's Drawing of the Annular Nebula in Lyra.

Made in 1860 with his four-foot reflector.

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W.

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may sometimes be found in swarms behind panels and wainscoting in badly infected houses, the tracheæ can still be recognised as perfect tubes after all the rest of the soft parts have dried up and disappeared. All that it is necessary to do with the dried carcase is to soak it in water till it becomes sufficiently flexible to be manipulated without breaking. On cutting through the skin, the tracheal tubes will be found spreading about in various directions, and may be examined where they lie, or removed and placed between glass, when a high power may be brought to bear upon them. There is no object in insect anatomy that is more easily identifiable than these breathing tubes, or more easily demonstrable, and hardly any that forms a more beautiful and attractive subject of study or exhibition.

(*To be continued.*)

Notices of Books.

Soils and their Properties. By Dr. W. FREAM, B.Sc., LL.D. (George Bell and Sons, London.) This book will form a welcome addition to the library of the scientific farmer. It gives a brief account of the constitution of soils in different parts of the British Isles, tracing them back to their parent rocks, and describing, without too much technicality, their more important physical and chemical properties. A soil composed entirely of one constituent rock frequently lacks the essential elements of fertility. Thus a pure clay, a pure limestone, or a pure sand is incapable of growing crops, whereas a soil consisting of a suitable mixture of these ingredients is likely to be very fertile.

> All gravel and sand is not the best land:
> A rotteny mould is land worth gould.

The reason that alluvial soils are generally so fertile is the mixed character they possess, owing to their having been derived from the disintegration of various kinds of rocks. Not uncommonly the admixture of a rock that supplies the deficiencies of another takes place naturally along the line of outcrop of two geological formations of very different character. Dr. Fream's book is full of suggestions likely to stimulate the farmer to close observation of the processes of decay of rocks, of the action of water, drainage, frost, and wind, and of the work of the little micro-organisms which appear to act as the carriers of nitrogen between the enormous reservoir of the element contained in the atmosphere and the roots of plants.

Monograph of the British Cicadæ. (Parts 3 and 4.) By G. BOWDLER BUCKTON, F.R.S. (Macmillan and Co.) In these two parts the genera and species from *Dicranotropis* to *Euacanthus* are described and illustrated, and most of the largest and best known of our species thus come under review. The dryness of descriptive details is relieved in Part 4 by some exceedingly interesting matter of a more general character, and questions such as those relating to the sound-producing apparatus of the chirping *Cicadæ*, and the condition of the organs of special sense in the froghoppers generally, are ably discussed. The attractive but little worked subject of life histories comes in for a brief notice, though very little light can be thrown upon it. There are great difficulties in the way of the artificial rearing of insects such as these, which subsist entirely on the juices of living plants; and even when the observer is successful in keeping the insects alive in confinement for any length of time, the secrecy of some of their operations, combined with the smallness of their size, renders the task of watching them doubly difficult. Mr. Buckton records some interesting observations made on the beautiful green *Tettigonia viridis*, Linn., one of the handsomest of our species, a colony of which he kept for some weeks under glass shades within which rushes were growing; but even under such favourable conditions, he failed to discover the mode of oviposition. A curious figure is given of a mass of "cuckoo spit," which had hardened into a reticulated ball containing the dead insect within it.

An Illustrated Handbook of British Dragonflies. By the EDITOR of the "NATURALIST'S GAZETTE." (Naturalists' Publishing Co., Birmingham.) There are scarcely any insects so misunderstood, popularly, as Dragonflies, and to all who would like to know the truth about them, we would recommend a perusal of this capital little manual, in which the author has put together all that a beginner needs as an introduction to the study of the group. There are descriptions of all the British species, forty-five in number, as well as an accurate account of their structure, habits, and life history, and instructions as to collecting, preserving and rearing them. A number of excellent illustrations, exhibiting most of our commonest species and their transformations, adorn the pages, and will be found a most useful aid to the student in his indentifications. We congratulate the author on having produced a thoroughly useful and reliable little handbook, which will, we trust, speedily find its way into the hands of many entomologists.

THE ANNULAR NEBULA IN LYRA.

BY A. C. RANYARD.

WE owe the photograph of the Ring Nebula in Lyra, shown in the plate, to the courtesy of M. Trépied, the Director of the Observatory at Algiers. It is an enlargement from a photograph taken by him with an exposure of six hours in the principal focus of one of the 13-inch achromatics which have been prepared by the Brothers Henry for the international work of the photographic survey of the heavens. It was taken in August last, and was one of the first-fruits of the instrument after it was mounted at the Algiers Observatory. The photograph was made with two exposures on successive nights, the sensitive plate having been covered up and removed in the meantime, and replaced when the instrument had been brought into position by means of the finder with which the driving is controlled. It has since been enlarged 64 diameters, and the granulation of the original plate shows very obviously; the minute specks composing the nebulous ring must not, therefore, be mistaken for stars.

To the right hand of M. Trépied's photograph is a photographic reproduction of Mr. Lassell's celebrated drawing of the Nebula, made with his four-foot equatorial in 1860. Mr. Lassell's drawing is turned with the North point uppermost on the page, and the west or following side towards the right hand, and the photograph is turned to correspond in orientation with Mr. Lassell's drawing. The scale of our reproduction of Mr. Lassell's drawing is $1'' = 0{\cdot}015$ of an inch. It will be noticed that M. Trépied's photograph shows the central star as nebulous, and the rest of the field inside the annular nebula comparatively dark and not filled up with nebulosity as in Mr. Lassell's drawing. The central star also appears nearly symmetrically situated with respect to the elliptic ring of nebulosity, whereas in Mr. Lassell's drawing it is decidedly to the north-east of the centre. In describing it, Mr. Lassell says: "The star a little below the centre of the dark space in the Nebula is faint, and from its faintness, in

conjunction with my impression that it does not always appear precisely in the same place, I think that there may possibly be two nearly equal stars there, too faint to produce distinct sensations on the retina. I see no other stars whatever in the Nebula, nor have I the impression that even the brightest parts would break up into stars, even with far more optical power."

As is well known, the Nebula has since been shown to be gaseous; but M. Trépied thinks that in the original negative he has evidence of at least three small stars in the brighter parts of the ring. It will be noticed that the outline of the ring in M. Trépied's photograph is more nearly circular than in Mr. Lassell's drawing. The decrease in brightness of the ring near to either end of the longer axis of the ellipse is a marked feature of the Nebula, as seen in the telescope, and is shown in the drawings of Trouvelot (*Annals of Harrard Observatory*, Vol. 8, Plate 34) and Holden (*Washington Observations*, 1874, Plate VI). The fainter light of the extremities of the ellipse is also mentioned by Padre Secchi in the *Descrizione del Nuovo Osservatorio del Collegio Romano*, Rome, 1856, page 86. The decrease of brightness at the ends of the ellipse is also very distinctly recognizable in M. Trépied's photograph, and the southern side of the ring appears distinctly brighter than the northern.

The Nebula has also been photographed by Mr. Isaac Roberts, 31st July 1887, with an exposure of 20 minutes, in the principal focus of his 20-inch reflector; still more of the Nebula is shown upon his photograph, and the exposure has gone so far that the density at the ends of the ellipse is barely distinguishable as less than that at the sides. There is also a small projection or irregularity of the ellipse at the south-west end, which is well shown in the drawings of Trouvelot and Holden; but, curiously, neither of these observers show the star or nebulous mass at the centre, which is so clearly shown in M. Trépied's photograph as well as in that of Mr. Roberts, and in a small photograph taken by Herr Von Gothard in 1886. A valuable account of the chief drawings of this Nebula made up to 1875, is given in a paper by Prof. E. S. Holden, published in the *Monthly Notices* for December 1875.

The following fuller list of drawings and descriptions of the Nebula I owe to Mr. Sadler:—

Herschel, Sir John, "Phil. Trans.," 1833, Plate X., Fig. 29. Very symmetrical ellipse.

Earl of Rosse, "Phil. Trans.," 1844, Plate XIX., Fig. 29. A curious drawing, with parallel bands of nebulosity in the interior, and wisps of nebulosity from the outside of the ring.

Sadler, "Engl. Mech.," Oct. 13, 1882, Misprint No. 2 for No. 1. Symmetrical drawing, giving places of small stars.

Brashear, "Engl. Mech.," Nov. 14, 1884. Symmetrical ring, ellipse too narrow.

D'Arrest, "Instrumentum Magnum Equatoreum," Plate 11, Fig. 5.

D'Arrest, "Siderum Nebulosorum Obs. Havnienses." Symmetrical sketch; no central star.

Holden, "Washington Observations," about 1875 or 1876. One of the best drawings, but no central star.

Trouvelot, "Astron. Engravings from Harvard Obs.," Vol. 8, Plate 34. Very good drawing; several small stars are shown in the nebulous ring, but none at the centre.

Lamont, "Annall Munich Obs.," Vol. 17, Plate 11, Fig. 14. Small symmetrical drawing.

Lassell. Drawing privately published; copy in Astronomical Society's rooms.

O. M. Mitchel, "Sidereal Messenger," July 1846. Description, but no drawing.

The photographs of Jupiter and Saturn given in the plate are remarkable as showing the very different actinic action of the light from different parts of the discs. The light from the Polar regions of both Jupiter and Saturn has hardly impressed itself on the plate. The light from the equatorial regions of Saturn also seems to be deficient in actinic power.

THE COAL-FIELDS OF CENTRAL FRANCE.

By G. W. BULMAN, M.A., B.Sc.

THE coal-fields of Central France present some interesting peculiarities. In the north of that country the coal-bearing strata are a continuation of the Belgian coal-field, and, as was suggested by Godwin-Austin in 1856, and practically proved by the recent discovery of coal in Kent, are connected with the South Wales and Somersetshire basins.

The isolated, basin-shaped areas in which our coal measures lie is attributed to folding, and subsequent denudation of the higher and more exposed parts; but the coal of Central France occupies areas which were depressions in the older rocks before the time of its formation.

The whole question of the origin of coal is a difficult one, and admittedly unsettled. It is true there is a generally received theory, which assumes that there was a gradual sinking of the surface, with pauses during which beds of vegetable matter were formed by terrestrial growths *in situ*, but it confessedly presents many difficulties.

One of the most important contributions to recent geological literature is a work by M. H. Fayol on the French coal-fields, in which the theory of growth *in situ* is entirely rejected. At the commencement of his practical work in the coal-mines of Commentry, this gentleman, fresh from l'Ecole des Mines, and imbued with the prevailing theory—*la théorie des tourbières*, he calls it—was brought face to face with phenomena which, to him, were inconsistent with it. Twenty-six years' experience, during which he has had exceptional opportunities for studying the question, has led him to discard the generally received idea, and bring forward the theory that the coal-measures of Commentry are old lacustrine deltas.

Specially conceived to explain the phenomena of this area, M. Fayol's theory has naturally been extended to the rest of Central France, and to coal-fields in general. "I propose to show," he says, "that coal-measures are deposits formed by water-courses at their entrance into lakes, or into the sea." And whatever may be thought of this extension of his views, it must be admitted that if any case can be proved by scientific reasoning, experiments, and observation, M. Fayol has proved his for the coal-field of Commentry.

Every phenomena exhibited by these coal-measures can, he claims, be satisfactorily explained on his theory, and imitated in an artificial delta. On the other hand, he points out many facts which the rival theory utterly fails to account for.

The first section of the second part of his book is the record of the examination of the rocks of the coal-measures. It is remarkable for its minuteness, and the amount of labour it implies. The description is illustrated by numerous and elaborate plans and sections, which serve admirably their purpose of elucidating the text.

The coal-basin of Commentry is one of those numerous isolated formations scattered over the granitic and gneissic plateau of Central France. It is some $5\frac{1}{2}$ miles by 2 in

extent, and 2,296 feet thick, and lies in a depression in the older rocks. One of its most notable characteristics is the large proportion of coarse materials—80 per cent. of the strata are conglomerates, and similar rocks; in our own coal-measures conglomerates are the exception. We have also to note the want of parallelism among the beds; the great variation in nature and thickness of individual strata; that beds and sets of beds frequently disappear; the frequent occurrence of false bedding; that fragments of granite, sandstone, and other rocks are found in the finer grained deposits; the black sandstones which contain coal in all dimensions, from microscopic particles to masses and beds several yards in thickness.

The chief coal seam is known as *la Grande Couche*, of which a detailed description is given. It is chiefly remarkable for the great changes in thickness and composition which it undergoes. When followed from point to point it is found to change from an ordinary bituminous coal to cannel, boghead, bituminous shale, and even to sandstone and conglomerate. In thickness it varies from 0 to upwards of 90 ft. Sometimes the seam is pure coal from the floor to the roof, with a thickness of from 32 to 75 ft.; sometimes there are intercalations of shale, and even sandstone and conglomerate, which may reach a thickness of 26 ft. No fire-damp is disengaged from this seam, in which it differs from some of the other seams of the basin, but carbonic acid gas occurs. Towards the west it splits up into six different seams.

In our own country the enormous 30-feet seam of the Dudley coal-field breaks up into ten or fourteen different seams, and in the coal-measures of Northumberland and Durham it has been noted that most of the seams, when followed far enough, coalesce with some other seam. The roof and floor of the seam are variable both as to nature and form. The former is often of shale, and sometimes contains blocks of granite and quartz: it is frequently irregular, and contains fragments of coal mingled with the shale.

Below, the line of junction is also irregular, the coal frequently denticulating and digitating with the bed below. In many places, also, the coal has been eroded. It was the constant presence below the coal of fire-clay full of stigmaria in the Welsh coal-fields which led Sir Wm. Logan to the conclusion that these clays were ancient soils, and to the general adoption of the theory of growth *in situ*.

But, says M. Fayol, in the whole coal-field of Commentry there is not a single bed which resembles an ancient soil. The *Grande Couche* rests sometimes upon carbonaceous shale, sometimes upon sandstone, sometimes on conglomerate: in no part of the floor are there to be found traces of atmospheric action. All these details of the seam are illustrated by plans and sections.

M. Fayol takes us to precarboniferous times, and restores, from geological evidence, the physical features of the district when the deposition of the coal-strata began. The coal-measures lie in a depression in the older rocks which consist of gneiss, granite, granulite, mica-schist, micro-granulite, porphyries, &c. A careful study of the composition of these is a needful preliminary to the study of the lithology of the coal-measures.

The laborious method of percentages employed by M. Fayol in this part of his work is one which has yielded many valuable results in various branches of geological research. Here it leads to the division of the coal-field of Commentry into several distinct lithological zones, shows the origin of the sediments, and enables us to follow step by step the formation of the strata. The method is as follows:—

Every pebble in a portion of a given bed is taken, and its nature, form, and size are noted. Then the percentage of each kind of rock at many different points is calculated. From this work it soon appears that these pebbles are identical with the previously studied rocks of the older formations. Moreover, the percentage of a certain rock is found to increase in one direction and decrease in another. This indicates at once the direction of the source from which that particular rock was derived, and the previous study of the surrounding district points to the place of the parent rock.

"I have found in the neighbouring mountains," says M. Fayol, "the origin of the greater part of the elements which enter into the formation of the coal-measures." The old rivers which brought the pebbles must have flowed along the lines thus laid down. The form of the pebbles further indicates the nature of the stream, and so gradually the shadowy outlines of the past fix themselves: the physical geography and climate of the carboniferous period in Central France are restored. An Alpine district appears. High and steep mountains of granite, granulite, and mica-schist surround a number of deep, but not large, lakes, scattered over the central plateau. Rain and atmospheric influences are at work, and pebbles, sand, mud, and vegetable matter are carried down into the lakes. Gradually the valleys are deepened, and the lakes filled up by the torrential water-courses from the hills. That of Commentry is fed chiefly by a mountain stream from the north, which enters by the valley of Bourrus, and another from the west, which enters by that of Colombier: the water flows out to the south by a single outlet.

Each stream forms its own delta, and these gradually increasing join each other, and finally fill the lake. A series of illustrations show how the deltas of the different streams approached each other.

Vegetable *débris*, and the finer sediments, are deposited in the creek between the two chief deltas, and form the chief coal-seam of Commentry—*la Grande Couche*. Another creek, on the other side of the delta, receives the vegetable *débris* which goes to form the coal-seam of Ferrières. In his experiments on sedimentation M. Fayol has shown that pebbles, sand, mud, and vegetable remains, carried by the same stream, may thus be deposited in separate beds. While these beds were being laid down, a geological incident took place which has left its mark among the rocks of Commentry. A huge landslip occurs among the mountains: the stream is dammed back, accumulates behind the barrier, and then with a mighty rush breaks through, and carries with it enormous masses of rock. Large angular blocks of stone are deposited among the strata of the lake. It is to be noted that Mr. Godwin-Austin, writing of these coal-fields of Central France, attributes the large blocks to the action of ice. But, according to M. Fayol, no trace of glaciers has been met with.

The climate of the period, as indicated by the great variety of the plants and insects, was warm and moist, like certain regions situated near the tropics at the present day. Rains were abundant, but not diluvial or extraordinary. That the streams which carried the fragments of granite, gneiss, &c., from the mountains, brought also the vegetation of the period to be thus separately deposited to form coal is M. Fayol's most important result. The form of the basin, he points out, and the coarse nature and lie of the beds, indicate a deep lake surrounded by high mountains, and fed by mountain torrents: the relations of the coal-seams to the other beds precludes the idea of intervals during which the area formed swamps for the growth of coal *in situ*.

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Some interesting calculations as to the time required for the formation of the coal-measures are given. On the hypothesis of *growth in situ*, and a gradual sinking of the surface, 800,000 years would be required; for the hypothesis of deltas, 16,000 years; *la Grande Couche*, on the former view, would require 318,500 years, and on the latter, 2,500.

On arriving at the question of the origin of coal, M. Fayol asserts that *all* the varieties in the coal-field are formed directly by vegetable *débris* similar to that usually carried by streams. Vegetable fragments found carbonized in shales and sandstones are usually ascribed to drift, and since there is a gradual passage from such beds to pure coal, there is no reason to doubt that these latter may be formed in the same way.

A bed of conglomerate 26 ft. thick, intercalated with the chief coal-seam, presents great difficulties on the theory of original horizontality and growth *in situ*, but is easily explained on the hypothesis of deltas. An unusually severe flood carries coarse particles beyond the ordinary resting-place of such, and deposits them on a bed of vegetable *débris*; things return to their usual course, and nothing but vegetation is laid down on the gravel. Floods and changes of watercourses cause the coarser sediments to invade the finer; the latter are then found intercalated with the former. The numerous local disturbances which occur are easily explained as the result of the pressing out of the soft incoherent beds of mud by the weight of the sediment above.

The pebbles of granite found in the coal itself are thought to have been carried by the trees which form it. When the rivers cut through some already bedded vegetable matter, this, being denser by reason of the change already undergone, is deposited *with* the sand, and "black sandstones" are the result.

The cleavage of the coal, M. Fayol explains as a phenomenon of contraction. Upright trees occurring in coal have usually been taken as indications of growth *in situ*; and since such occur in the coal-basin of Commentry, it becomes necessary to show that they do not necessarily imply this.

M. Fayol shows that *upright* trunks form only a small percentage of the large number occurring in his special area; as the beds become coarser and less carbonaceous, the proportion of upright trunks increases; the rocks which contain the fewest trees have the largest proportion upright. And some of these perpendicular trunks are upside down, with their roots in the air! Many are without roots, and others have their roots damaged and bruised. Moreover, the roots of these upright trees have often greatly affected the stratification of the beds in which they lie: roots growing in the soil would not do so.

To ascertain the effect of heat and pressure on sediments containing vegetation, some experiments have been tried. Various animal and vegetable remains have been placed with water in tubes, boilers, &c., for various periods of time, and sometimes enveloped in sand, mud, &c. The following results have been obtained: At 15° to 20° C., under a pressure of 65 yards of water, an inflammable gas has been produced. Organic matter protected from the air decomposed very slowly; the rate of decomposition grows slower as time passes. Woody fibres, fibrous bark, and the epidermis of leaves and grains resist best; cellular portions, young branches, interior of grains, &c., decompose first. Weight is lost, and the residue becomes more carbonaceous. The alteration is about the same, whether the vegetable matter is in contact with water, or enveloped in earthy sediments.

One of the most interesting sections of the book is that devoted to the phenomena of sedimentation. In his numerous and beautiful experiments, M. Fayol has produced in miniature every peculiarity of the coal-field of Commentry. As a general conclusion, both from natural and artificial deltas, M. Fayol divides each into two parts, which he terms Alluvial and Neptunian respectively. The latter consists of beds inclined at angles of from 0° to 45°, and the former are spread over them horizontally, or nearly so.

In tranquil water the coarser materials are deposited in steep slopes, as if they had been tipped from a waggon; the finer sediments in agitated water are spread over greater distances and may be nearly horizontal. The dip of the beds increases with the coarseness of the materials, the feebleness of the current, the smallness and the tranquillity of the basin, and *vice versâ*.

Sometimes a third set of beds, nearly horizontal, and *below* the Neptunian part, may be observed.

Highly inclined beds of coarse grain, then, are likely to have been formed in lakes fed by Alpine torrents; horizontal beds of fine grain point to fluvio-marine conditions. Hence the inference that the irregular, inclined, and coarse beds of the coal-fields of Commentry have been formed in an Alpine lake; while the more extended, finer, and more horizontal strata of the northern French coal-field are ascribed to fluvio-marine conditions.

M. Fayol claims that there is not a single peculiarity of the coal formations which is not to be found in the deltas of the present day, and imitated in artificial deposits.

These experiments and observations on sedimentation have a value far beyond their immediate application to the coal-fields of Central France. They will be found of great value in explaining the general phenomena of stratification.

If M. Fayol's theory is correct, it follows that the inclination of the strata in the coal-field of Commentry is *not* due to subsequent earth movements, but is the original position of the Neptunian part of the delta. Consequently, he has to do battle with the geological axiom of the original horizontality of aqueous deposits.

M. Fayol goes into the history of this hypothesis, and points out that it was first formulated by Stenon, a native of Denmark, in 1669.

The fact that flat pebbles in inclined strata lie parallel to the bedding, is considered one of the strongest proofs. But, as we have seen, this is the natural position taken in beds originally inclined.

The horizontality observed in alluvial beds at the mouths of rivers is another supposed proof. These, however, are only the *horizontal covering* of the *inclined* Neptunian beds.

The regular thickness of marine beds, and the feeble inclination of the sea bottom, is thought to show that all beds must be nearly horizontal when first laid down. But a gentle inclination of the bottom does *not* prevent the formation of *steeply inclined* beds near the mouth of a river. Thus the bottom of the Mediterranean has a feeble slope, and yet, at the mouth of the Var, deposits, inclined at angles of from 25° to 30°, are formed. A similar inference is to be drawn from the experiments.

Nor do beds of vegetable matter at various heights in deltas *necessarily* imply horizontality; they are found at all inclinations between 0° and 40°, and can, as experiment shows, be formed by vegetation carried by streams.

The convenient hypothesis of movements of the earth's crust has, perhaps, been too freely invoked for the explanation of geological phenomena; it is well to have it thus brought home to us, that in some cases we may dispense with it.

Letters.

[The Editor does not hold himself responsible for the opinions or statements of correspondents.]

FRACTIONAL VALUES FOR π.

To the Editor of KNOWLEDGE.

SIR,—Will you allow me to submit to your readers what is, I believe, a new approximation for the number π, and which expresses the ratio of the circumference of a circle to its diameter more accurately than any other fractional approximation I have heard of?

Among the ancient Egyptians* the ratio was taken as $(\frac{8}{9})^4$, which is equal to 3·160,493,8 . . . . .

The true ratio being

3·141,592,653,589,793,238,462,643,38 . . .

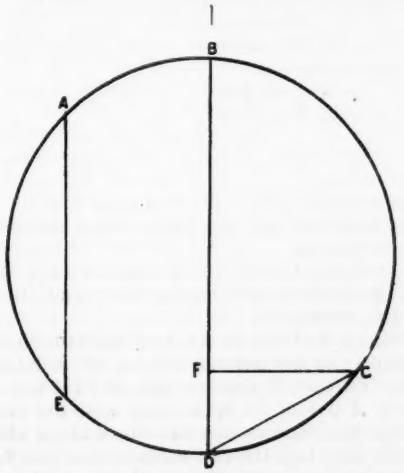
the Egyptian value shows an error in excess of ·018,901 . . . or about one-fiftieth part of the diameter.

Archimedes showed that π was less than $3\frac{1}{7}$, and greater than $3\frac{10}{71}$. After this achievement of the Greeks, no great advance was made towards the truth until the sixteenth century. The Hindus, about the year 500 A.D., used $\frac{3927}{1250}$ = 3·1416 as the ratio. This is near enough for all practical purposes, but is not sufficiently easy of construction.

In the sixteenth century a man named Adrian, a native of Metz, gave as the value $\frac{355}{113}$ = 3·141,592,9 . . . which is correct to the sixth decimal inclusive. But this is not much easier of construction than the Indian value.

For all ordinary purposes the best way to draw a straight line approximating in length to the circumference of a circle is to take three diameters *plus* one-fifth part of the side of inscribed square. We thus obtain a straight line equal to 3·141,421,356,237,3 . . . . .

This shows an error in defect of ·000,171,297 . . . . . or less than one five-thousandth part of the diameter. It is not necessary to construct with greater accuracy, but, nevertheless, whilst looking for a nearer coincidence, I one day lighted upon the following:—



Let ABCDE be a circle, the diameter of which is taken as unity, and AE the side of an inscribed square; BD is any diameter; $FD=\frac{BD}{5}$ FC is drawn at right angles to BD, and meets the circumference at C. The points C and D are joined by the straight line CD.

Now if we draw a straight line equal to three times DC, *plus* one and a third of AE, *plus* six-sevenths of BD, we shall approximate with marvellous accuracy to the circumference of the circle.

Thus:

$$3\,DC + \frac{4\,(AE)}{3} + \frac{6\,(BD)}{7} = 3{\cdot}141,592,685,22\ldots$$

showing an error in excess of ·000,000,031,63 . . . . . or less than the thirty-millionth part of the diameter. By the above method, therefore, if it were possible to draw with perfect accuracy, an engraver might, in a few minutes, construct a straight line so nearly equal to the circumference of a given circle *that even in a diameter of thirty miles the error would be less than the sixteenth part of an inch.*

It is easily seen that in the above figure $DC=\frac{\sqrt{5}}{5}$; whilst $AE=\frac{\sqrt{2}}{2}$. Thus, since $\sqrt{5}$=2·236,067,977,5 . . . . .

and $\sqrt{2}$=1·414,213,562,4 . . . . .

$$\frac{3}{5}\sqrt{5} + \frac{2}{3}\sqrt{2} + \frac{6}{7} = 3{\cdot}141,592,685,22\ldots$$

I am, Sir,

Your obedient servant,

September 27th, 1890. GERARD DANIEL.

To the Editor of KNOWLEDGE.

DEAR SIR,—Will you inform me if there is anything to be done with a really good chronometer which has been badly magnetised through a visit to some electrical works, the proximity to the powerful magnets there employed causing an error of several seconds daily which cannot be rectified?—Yours truly,

C. PARKINSON.

[The watch may be demagnetised by placing it in a magnetic field produced by a coil through which a powerful alternating current is passing. The intensity of the correcting magnetic field should be at least as great as that which originally caused the derangement, and the watch should be slowly withdrawn from the coil through which the alternating current is passing. Mr. Common, in the *Observatory* for November 1889, gives an account of the demagnetisation of a chronograph watch which he had badly magnetised by going too near to a dynamo at work, so that from a rate of fifteen seconds gaining, a losing-rate of from five to six minutes a day had been caused. He took it to the chief engineer of the electric lighting works of Paddington Station, who placed it within a coil used for the purpose, through which an alternating current of about 140 volts was passing, and turned it about slowly, withdrawing it while doing so. The result was perfectly successful, and the watch at once returned to its old rate of fifteen seconds gaining.—A. C. R.]

THE WORD "BROAD."

To the Editor of KNOWLEDGE.

DEAR SIR,—The great English Dictionary now in course of publication is not only admirable for the abundance of information it contains, but also for the care with which its able Editor keeps within the limits of ascertained fact. One instance of this is found under the word *Broad*, the

* This appears from a calculation found in the Rhind papyri.—A. C. R.

various forms of which are given, and then the frank statement that "no related words are known, even in Teutonic, except its own derivatives: see Breadth, Brede."

After such a confession by this high authority, I shall surely offend no prejudices by venturing to suggest some "related words" which appear to have been overlooked.

By the simplest form of metastasis [*cf. brydde = bird*] we get to the word *Board*, a broad extended surface of wood, a word for which the Dictionary offers nothing better than tentative suggestions as to its correlations. The Dutch word *bord* is used for a plate or trencher, that being an extended surface; and the old English word *Bred* for "a board, or tablet," gives another congener of *Broad* or *Board*. But what about the word *Bread*? This word is left to surmises by the Dictionary, because it did not occur to the writer that *bread* derived its name from the shape of the *broad* flat cakes which were the first representatives of the loaf. The failure to recognize this alliance is the more remarkable when we remember that the word *bread* survived in its primitive sense (when applied to ships' biscuits) down to the 18th century. A similar word is *Brad*, which the Dictionary itself defines as "a thin *flat*tish nail"; its *broad*ened shape being the cause of its name.

The common interchange of *l* and *r* accounts for the old word *Blad*, "a firm *flat* blow," and this brings us to *Blade*, a word always expressive of that which is *broad*, whether it be a blade of grass, the blade-bone, or the blade of a knife, sword, or paddle. This is clearly seen in the southern Scotch use of the word *blade* for the broad outer leaves of cabbage, lettuce, &c.; and in the German restriction of *blatt* to a leaf, while *laub* (*i.e.* leaf) is applied to foliage in general. And do not the words *Plate*, *Platter*, a *Plot* of ground, and a grass-*Plat*, give us other variants of the interchangeable letters *p-l-t*, *b-l-t*, *b-l-d*, *b-r-d*, in the sense of extended surface?

The well-known change of *p* to *f* brings the word *Flat* itself into the series; for is not every flat surface a broad or extended one? Surely no philologist of the narrowest school will deny that the Greek πλατυς is basically connected with the word *plate*, and that both are allied to the Sanskrit *prath*, "to extend." The Sanskrit word for *broad* is *prithu*, in which we find the labial, semi-vowel, and dental, just as in the European languages; and *prithwî* is the name of the earth because of its extended surface.

The framework of all the words here adduced is—

Labial.		*Semi-vowel.*		*Dental.*
f	-	l	-	t
p	-	l	-	t
b	-	l	-	t
b	-	l	-	d
b	-	r	-	d
p	-	r	-	t

It is not pretended that these words are derived from each other, but that they are most certainly basically connected together, and may fairly be used to modify the statement that "no related words [of Broad] are known, even in Teutonic, except its own derivatives."

Frederic Pincott.

WET DAYS IN SUMMER.

To the Editor of Knowledge.

Sir,—Looking through the records of rainfall at Greenwich since 1841, I have met with a fact which I do not remember to have seen pointed out before, and which seems to deserve the attention of meteorologists, farmers, and others.

It is, that the character of June, as regards rain, is to some extent a key to that of the rest of the season (meaning by "season" the four months June to September). More often than not, if June is wet, the three other months (viewed as a whole) are wet; if dry, dry. We may, if we like, frame a statement which has wider, and nearly universal, application, thus:—

Where we find a wet June we find a wet season; where a dry June, a dry season.

Here we include those cases in which the excess or defect of June makes the season wet or dry, though the remaining three months may be average, or dry (in the case of excess), or wet (in the case of defect).

I have measured wetness by the number of wet days, meaning by a wet day one on which at least one-tenth of an inch has fallen. A wet month, season, or other period, will be understood to mean one with more than the average number of wet days.

If anyone will take the trouble to make out a curve of the number of wet days in June, and another of the wet days in the whole season, or in June–September, he will find a remarkable correspondence.

Those forty-nine seasons may be classified in the following way, which brings out very well the matter to be explained:—

	Reckoning: By wet days.	Reckoning: By all days of rain.
A. Wet seasons with June wet—		
a. June wet and rest of season wet ...	12	13
b. ,, ,, ,, average	2	1
c. ,, ,, ,, dry ...	1	5
B. Dry seasons with June wet	3	2
C. Dry seasons with June dry—		
a. June dry and rest of season dry ...	16	16
b. ,, ,, ,, average	1	3
c. ,, ,, ,, wet ...	1	1
D. Wet seasons with June dry	1	2
E. Seasons with June average—		
a. Wet seasons	6	2
b. Dry seasons	3	3
F. Average seasons—		
a. June wet	1	0
b. June dry	2	1
	49	49

I have added a column in which all days of recorded rain are considered, and the results seem still better than in the first column.

Thus, excluding Class *E* (with June average), we have in *A* and *C* the instances proving the rule; while *B*, *D* and *F* contain the exceptions.

Accordingly we find: in the first column, 33 instances, 7 exceptions; in the second column, 39 instances, 5 exceptions. Further, it appears that, in 12 years out of 19 (or nearly 2 out of 3), with June wet, the rest of the season was wet; and in 16 years out of 21 (or about 4 out of 5), with June dry, the rest of the season was dry. (The corresponding figures for all days of rain are 13 out of 21, and 16 out of 23.)

It will be asked, Do these facts at all help us, at the end of June, to forecast more definitely the character (number of wet days) of the next three months? I think they do.

If we group together all the Junes which had the same number of wet days, and compare, for each group, the

corresponding numbers of wet days in July to September, we find these latter not alike, of course, but varying within limits. Their averages form, on the whole, an ascending series (ascending with the number of wet days in June). And by studying these averages and their variations, one is able, I think, to limit the range of probability not inconsiderably. I will not trouble you with details (which may be had, if desired).

Last June was very wet; it had 10 wet days. Our forecast for the three months would have been 22 (average and most probable number). The actual number is, I think, 19. The season falls under the category *A. b.* We might not always, of course, be so near the truth.

It would be interesting to know whether the above rule holds good elsewhere than in Greenwich, and this letter, if you are disposed to publish it, may perhaps usefully lead to observations on the subject.

The well-known old saying about St. Swithin's day is, of course, easily exploded by facts of observation. But the widespread impression (which may have had to do with the origin of that and similar sayings) that wet weather appearing about the time of the summer solstice tends to persist a considerable time, is perhaps to some extent explained by the facts above indicated.

Allow me to add another feature which has struck me in this inquiry. We seem to have a conspicuously wet June near the beginning (or end) of each decade; *i.e.* at about ten years intervals (say 10+2). This is the case with 1848, 1860, 1871, 1879, and 1890; and all the higher maxima (say above 9 wet days) are thus included. Taking the Chiswick record, we may add the years 1830 and 1838.

I am, Sir, yours truly,
Alex. B. MacDowall.

THE ASTRONOMICAL AND PHYSICAL SOCIETY OF TORONTO.

To the Editor of Knowledge.

Dear Sir,—In the interest of your Canadian and more distant subscribers, of whom four at least are members of this Society, I venture to invite your attention to a subject which has been discussed by us, and which we trust will commend itself to your favourable consideration.

Under the most toward circumstances, Knowledge does not reach us earlier than about the 23rd of the month of issue. The last number was delivered to us on the 23rd of September, the day of arrival. As you will readily see, the greater portion of the astronomical memoranda edited by Mr. Herbert Sadler is therefore of no value to us. This we much regret, and it has occurred to us that we might be allowed to suggest the propriety of so amending Mr. Sadler's plan as to permit his notes to extend over the earlier half of the following month at least. We have also noticed that, as a rule, the events predicted are those which will be visible in England only, thus omitting many which would be visible, for instance, on this Continent. But we do not do more than mention this, as we believe you give up to this branch of information all the space you can spare.

That you may form some idea of the objects of the Society with whose permission I thus address you, I beg to enclose some printed matter which includes a clipping from one of the Toronto papers in which appear notices respecting our meetings, which are held at intervals of two weeks. The second paper by Mr. Gore will be read at an early day. At our last meeting portions of your article relative to the work of Mr. Higgs, of Liverpool, were read and commented upon by Mr. Elvins and Mr. Miller, who have made a special study of the solar spectrum and have written upon the subject. On Tuesday next, one of our members will read a paper prepared with a view to illustrating in a practical manner Mr. Higgs's method, and will show how photographic plates, by means of dyes, can be made sensitive to the less refrangible rays.

Yours very truly,
G. E. Lumsden,
Corresponding Secretary.

Toronto, Canada, 1st October 1890.

[Perhaps the best way to meet Mr. Lumsden's suggestion would be to bring Knowledge out ten days earlier. Mr. Sadler will in future include some of the more remarkable phenomena observable in America and India. Subscribers in the Australian colonies do not receive Knowledge till the month is entirely past. It is encouraging to learn that the articles are found sufficiently interesting to be read and discussed at such colonial meetings.—A. C. R.]

THE FACE OF THE SKY FOR NOVEMBER.

By Herbert Sadler, F.R.A.S.

THE increasing number of solar spots and faculæ shows that the long-delayed minimum has at last been passed. Conveniently observable minima of the variable star Algol occur on the 3rd at 8h. 7m. P.M.; on the 6th at 4h. 54m. P.M.; on the 23rd at 9h. 47m. P.M., and on the 26th at 6h. 38m. P.M.

Neither Mercury, Venus, nor Mars can be seen at all to advantage this month. Mercury is in superior conjunction with the sun on the 17th; the very great southern declination (28°) of Venus militates against her observation at the beginning of the month, when she sets one hour after the sun, while she only sets about ten minutes after that luminary at the end of November. As we intimated in the last number of Knowledge, our ephemeris of Mars is discontinued on account of his increasingly diminishing diameter and brightness, and his proximity to the sun.

Jupiter must be looked for very early indeed in the evening for any details of the markings of the disc, phenomena of the satellites, &c. to be seen. He sets on the 1st at 9h. 58m. P.M., with a southern declination of 19° 58′, and an apparent equatorial diameter of $38\frac{3}{4}''$. On the 30th he sets at 8h. 28m. P.M., with an apparent equatorial diameter of $35\frac{3}{4}''$, and a southern declination of 18° 56′. Jupiter describes a direct path in Capricornus during the month, but does not approach any star brighter than the 7th magnitude.

Saturn does not rise till midnight on the last day of November, so we defer an ephemeris of him till next month. Uranus is also for all practical purposes invisible to the amateur observer.

Neptune is excellently placed for observation, rising on the 1st at 5h. 43m. P.M., with a northern declination of 19° 42′, and an apparent diameter of $2\frac{1}{2}''$. On the 30th he rises at 3h. 45m. P.M., with a northern declination of 19° 33′. He is in opposition to the sun on the 27th, when he is distant from the earth about $2{,}679\frac{1}{2}$ millions of miles (solar parallax 8″·80). At last year's opposition, using the same parallax, he was about half a million miles less distant from us. He describes a short retrograde path in Taurus about midway between the stars E. and W. in that constellation.

November is a very favourable month for shooting stars. The most marked displays are the *Leonids* on November 13th and 14th, the radiant point being in R.A. 10h. 0m.

Decl. +23°. The radiant point rises about a quarter past 10 P.M. The *Andromedes* occur on the 27th, the radiant point being in R.A. 1h. 40m. Decl. +43°. The radiant point, which is circumpolar, souths at 9h. 13m. P.M.

The moon enters her last quarter at 4h. 13m. P.M. on the 4th; is new at 1h. 38m. P.M. on the 12th; enters her first quarter at 0h. 45m. P.M. on the 19th, and is full at 1h. 23m P.M. on the 26th. There will be a partial eclipse of the moon on the afternoon of the 26th, but as it is invisible in this country, and as only the two thousandth part of the lunar disc will be obscured by the true shadow, no further details need be given. The 7th magnitude star 5 Geminorum will disappear at 6h. 59m. A.M. on the 1st (three minutes after sunrise) at an angle of 145° from the vertex, and reappear at 8h. 4m. A.M. at an angle of 296° from the vertex. The 6th magnitude star 42 Leonis will disappear at 3h. 2m. A.M. on the 6th at an angle of 340° from the vertex, and reappear at 3h. 46m. A.M. at an angle of 267° from the vertex. The $5\frac{1}{2}$ magnitude star 39 Ophiuchi will disappear at 4h. 33m. P.M. on the 14th at an angle of 138° from the vertex, and reappear at 5h. 34m. P.M. at an angle of 267° from the vertex, the moon having set at Greenwich at the time. This is a very pretty double star, the components being of $5\frac{1}{2}$ and $7\frac{1}{2}$ magnitudes, and 12″ apart. The colours are orange and blue. At 5h. 3m. P.M. the same evening the 7th magnitude star B.A.C. 5831 will make a near approach to the lunar limb at an angle of 203° from the vertex. At 4h. 42m. P.M. on the 18th the $5\frac{1}{2}$ magnitude star 33 Capricorni will disappear at an angle of 148° from the vertex, and reappear at 5h. 35m. at an angle of 246° from the vertex. The 5th magnitude star 33 Piscium will make a near approach to the lunar limb at 3h. 43m. P.M. on the 21st (in sunlight) at an angle of 171° from the vertex, and the $5\frac{1}{2}$ magnitude star B.A.C. 17 will disappear at 5h. 59m. P.M. the same evening at an angle of 125° from the vertex, and reappear at 7h. 5m. P.M. at an angle of 268°. The 6th magnitude star 26 Ceti will make a near approach to the lunar limb at 8h. 22m. P.M. on the 22nd at an angle of 208° from the vertex, and at 11h. 0m. P.M. the same evening the $6\frac{1}{2}$ magnitude star 29 Ceti will disappear at an angle of 223° from the vertex, and reappear fifteen minutes later at an angle of 250°. The $6\frac{1}{2}$ magnitude star 35 Ceti will disappear at 1h. 6m. A.M. on the 23rd at an angle of 177° from the vertex, and reappear at 2h. 2m. A.M. at an angle of 312°. At 7h. 25m. P.M. on the 24th the 5th magnitude star 38 Arietis will make a near approach to the lunar limb at an angle of 176° from the vertex. The 7th magnitude star B.A.C. 2154 will disappear at 2h. 37m. A.M. on the 29th at an angle of 58° from the vertex, and reappear at 3h. 34m. A.M. on the 28th at an angle of 343°. The $6\frac{1}{2}$ magnitude star B.A.C. 2514 will disappear at 6h. 27m. A.M. on the 30th at an angle of 148° from the vertex, and reappear at 7h. 25m. A.M. at an angle of 271° from the vertex.

Whist Column.

By F. S. HUGHES, B.A.Cantab.

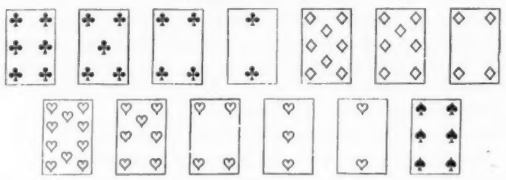
THE TURN-UP CARD.

BEGINNERS cannot be too often reminded of the great importance of remembering the turn-up card. Really good players often err in this respect, and even though they do not actually forget the trump card, neglect opportunities of fine play afforded by the information that may be given by means of it.

In many cases the dealer may be enabled to inform his partner of the position of trumps by playing a higher card instead of the turn-up. Of course he must be careful that his partner will not mistake the motive, as for example, by thinking that he is echoing when he has only three trumps.

An illustration is furnished by the following hand, which also shows how a player whose hand on paper appears hopelessly bad may by his skill in placing cards be the means of saving the game.

HAND NO. 15.



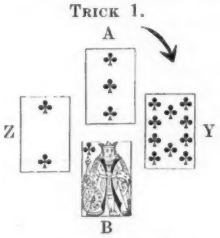
Z's Hand.

Score—Three all.

Z turns up the 4 of diamonds.

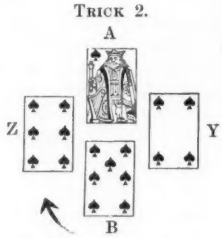
NOTE.—A and B are partners against Y and Z. A has the first lead; Z is the dealer. The card of the leader to each trick is indicated by an arrow.

TRICK 1.



Tricks—AB, 1; YZ, 0.

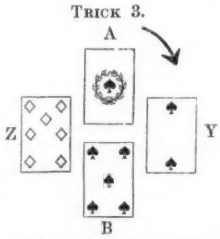
TRICK 2.



Tricks—AB, 2; YZ, 0.

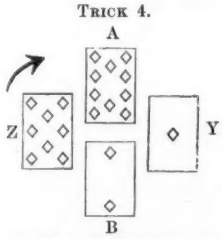
NOTE.—From his lead, A has not more than four clubs.

TRICK 3.



Tricks—AB, 2; YZ, 1.

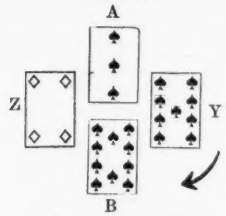
TRICK 4.



Tricks—AB, 2; YZ, 2.

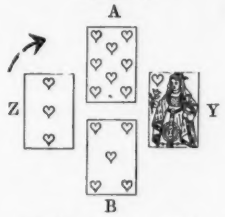
NOTE.—*Trick* 3.—Y has completed a call. Z can count the spades in the respective hands. B's lead of the 7 was obviously the penultimate, so that he has three cards of his suit remaining. The three is marked in A's hand, and he can have no more, as otherwise he would have led spades in preference to a weaker four suit (see *Trick* 1). Therefore Y has two spades remaining, and if B holds a ten ace over him, which is likely, Y must lose both his spades, if A leads through him. Z is bound to respond to his partner's call, but if Y goes on with trumps Z will be unable to ruff another spade. On this hypothesis, he reasons that if Y has only five trumps to one honour A B are almost sure to make two tricks in trumps and two more in spades, and thus go out by honours. Z therefore trumps with the seven and leads the eight, thus showing Y that he has still a trump—the turn-up—and can trump a spade, if Y wishes to give him another ruff.

TRICK 5.



Tricks—AB, 2; YZ, 3.

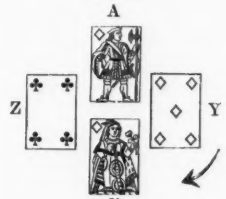
TRICK 6.



Tricks—AB, 2; YZ, 4.

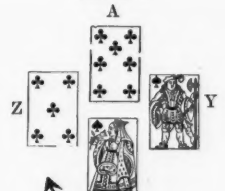
NOTES.—*Trick* 5.—Y grasps the situation and gives Z a ruff. *Trick* 6.—If A B are two by honours and B has the best spade, the game is still lost unless Y can make three tricks in hearts and clubs. Z therefore leads a heart in case Y wants to finesse.

TRICK 7.



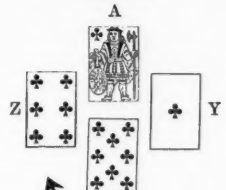
Tricks—AB, 3; YZ, 4.

TRICK 8.



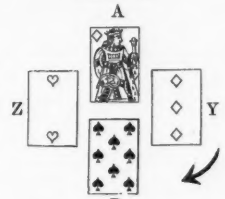
Tricks—AB, 4; YZ, 4.

TRICK 9.



Tricks—AB, 4; YZ, 5.

TRICK 10.



Tricks—AB, 5; YZ, 5.

Y makes the remaining tricks, and

Y Z WIN THE GAME.

A's Hand.	B's Hand.
D.—Kg, Kn, 10.	D.—Qn, 2,
C.—Qn, Kn, 7, 3.	C.—Kg, 9, 8.
H.—Kg, 9, 8.	H.—Kn, 6, 5.
S.—Ace, Kg, 3.	S.—Qn, 10, 8, 7, 5.
Y's Hand.	**Z's Hand.**
D.—Ace, 9, 6, 5, 3.	D.—8, 7, 4.
C.—Ace, 10.	C.—6, 5, 4, 2.
H.—Ace, Qn.	H.—10, 7, 4, 3, 2.
S.—Kn, 9, 4, 2.	S.—6.

Remarks.—It is very difficult to lay down general rules as to the degree of strength required to justify a call for trumps. In no part of the game is the personal equation of players more manifest. Amongst really good players there would probably be some diversity of opinion as to whether Y was strong enough to call. However, the knowledge of Y's hand that Z obtained at the end of the third trick enabled him to see that if Y had not two honours, or more than five trumps, the game was certainly lost, unless Y had the winning spade, or he himself could make another ruff. Z therefore acted on this hypothesis.

If Y had been uncertain whether Z had another trump, it would have been too risky to lead a spade, as he thereby lost the chance that B might finally be compelled to lead spades up to his second-best guarded.

G. SHAW.—The penalty for a revoke can only be claimed at the end of the hand.

Chess Column.

(CONDUCTED BY I. GUNSBERG.)

THE STEINITZ GAMBIT.

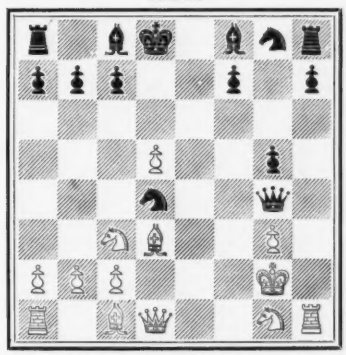
By G. H. D. GOSSIP.

WHITE.	BLACK.
1. P to K4	1. P to K4
2. Kt to QB3	2. Kt to QB3
3. P to B4	3. P×P
4. P to Q 4	4. Q to R5 ch
5. K to K2	5. P to Q4 or (A)
6. P×P	6. Q to K2 ch
7. K to B2	7. Q to R5 ch
8. P to Kt3	8 P×P ch
9. K to Kt2	9. Kt×P
10. P×P	10. Q to Kt5
11. Q to Ksq ch	11. K to Qsq

Zukertort played B to K2 at this stage in the last game of his match with Steinitz, but soon got into difficulties and lost.

12. B to Q3	12. P to KKt4

BLACK.



WHITE.

These moves occur in a game between Steel and Blackburne.

13. Kt to K4! best

Here Mr. Steel played 13. Q to K3, and lost. Had he, however, played the move I suggested above as best, he would speedily have gained an irresistible attack; for suppose now

13. P to KB3! best

(If 13. B to K2, 14. Q to B3 &c.; or if 13. P to KR3, 14. B×P ch, &c.).

14. Q to B3! best

This is much stronger than Q to B2, the move suggested by the Chess Editor of the *Australasian*.

	14. Kt to B4
15. B×P	15. P×B

If 15. B to K2, 16. B to KB4, &c.; or if 15. B to Kt2, 16. B to KB4, White having in either case a vastly superior game. If 15. B to Q3, 16. B×P ch, Kt×B or (*a*); 17. Q×Kt ch, K to Q2; 18. Q×R, winning easily.

(*a*) 16. K to Q2; (if 16. K to Ksq, White has a certain road to victory by 17. Kt×B ch, P×Kt; 18. B to QKt5 ch with a winning position); 17. B to QKt5 ch, P to B3; 18. P×P ch, again winning easily.

16. Q×R and White wins

The moves, therefore, of 11. K to Qsq and 12. P to KKt4 for the defence, introduced by Blackburne in this form of the Steinitz Gambit, are therefore unsound, and the defence of 6. Q to K2 ch, 7. Q to R5 ch, recommended by MacDonnell and Duffy, and considered best by the Editor of the *Book of the London Tournament* (1883), is inferior, as the subjoined analysis (approved by Herr Csank, of Vienna) will show. Repeating the ordinary moves in the Steinitz Gambit.

WHITE.	BLACK.
1. P to K4	1. P to K4
2. Kt to QB3	2. Kt to QB3
3. P to B4	3. P×P
4. P to Q4	4. Q to R5 ch
5. K to K2	5. P to Q4
6. P×P	6. Q to K2 ch
7. K to B2	7. Q to R5 ch
8. P to Kt3	8. P×P
9. K to Kt2! (best)'	9. B to Q3! (best)
10. Q to Ksq ch! (best)	10. QKt to K2! (best)

If 10. Q to K2; 11. B to KKt5, P to B3; (if 11. Q×Q; 12. R×Q ch, QKt to K2; 13. P×P, followed by Kt to K4, &c.); 12. P×Kt, P×B; 13. B to QKt5, P to QKt3; 14. Kt to Q5, Q×Q; 15. R×Q ch, K to Bsq best; (if Kt covers, then R×Kt, followed by Kt×P ch, &c.); 16. P×P, with a superior game. Compare Steinitz's notes on Steel's analysis in the *Book of the London Tournament* (1883), p. 61:—

11. P×P	11. Q×QP
12. Kt to KB3! (best)	

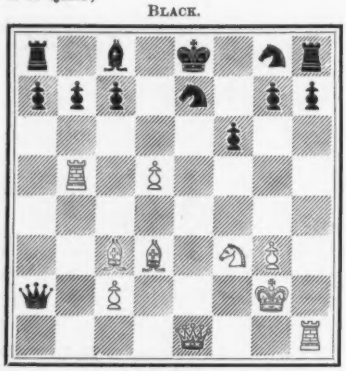
This and the next six moves of White constitute the Steel attack in the Steinitz Gambit, which Mr. Steel suggested as stronger than the continuation 12. R to R4 &c., adopted by Steinitz in a game, which he lost, in the London Tournament, to Tschigorin. For if now—

12. Q to Kt3,

and there does not appear to be any better move at Black's disposal, then follows:—

13. B to K3	13. Q×P
14. B to Q3	14. B to QKt5
15. B to Q4	15. P to KB3
16. R to QKtsq	16. B×Kt
17. B×B	17. Q×QRP
18. R to QKt5,	

BLACK.



WHITE.

and the game is dismissed in the *Book of the Tournament*, p. 61, with merely the remark "that White has a strong attack."

The subjoined analysis, however, will show that White can obtain a winning advantage in about half a dozen moves, *e.g.*

It is obvious that Black has only two moves at this juncture to avoid immediate loss, viz., P to QKt3 and Q to R3.

Now, if firstly:

	18. P to QKt3
19. Q to K2	19. Q to R3! (best)

If 19. Q to R6; 20. B to Kt4, and White must win, wherever the Queen goes, *e.g.* if (I.) 20. Q to R7; 21. R to Ksq, P to QR3; 22. B×Kt, K to B2; 23. R to Kt3, &c. If (II.) 20. Q to R5; 21. R to Ksq, followed by B×Kt, &c. Or if (III.) 20. Q to R3; 21. B×Kt, &c. Nor could Black play 19. Q to R5; on account of White's reply 20. B to Kt4, followed by R to Ksq, &c.

20. KR to QRsq	20. Q to Kt2! (best)
21. P to Q6! (best)	21. P×P

If 21. B to Kt5; 22. B to K4, &c.

22. B to K4	22. Q to Ktsq

If 22. Q to B 2; 23. B×R, Q×B; 24. KR×QRP, followed by the capture of the QKtP, and Black's game is utterly broken up.

23. B×R	23. Q×B
24. R×QKtP and must win.	

For if now: 24. Q to Q4; 25. R×QRP, &c.; or if 24. B to Kt2; 25. Q to Kt5 ch, B to B3; 26. R to Kt8 ch, K to B2; 27. R×Q, B×Q; 28. R (from QRsq)×QKtP, B to B3; 29. R to Q8, B to K5; 30. B to Kt4, and Black's game is untenable, since he must either lose a piece or permit the fatal advance of the White QBP.

If secondly:

	18. Q to R3
19. Q to K2	19. B to KKt5

If 19. Q to Q3; 20. B to Kt4, Q to Q2; 21. P to Q6, P×P; 22. R to Q5, with a terrible attack. For if now 22. Q to K3; 23. Q×Q, B×Q; 24. R×QP, K to B2; 25. R to Ksq, B to Kt5; 26. B to B4, &c.

If 19. P to QKt3, the position is resolved, by a transposition of moves, into that already examined above.

If 19. KKt moves; 20. R to Ksq, followed by 21. B to Kt4, and White wins.

If 19. K to Bsq, 20. R to QRsq, followed by B to QKt4, &c.

If 19. B to Q2; 20. KR to Ksq, Q to Q3!; 21. B to Kt4, P to B4; 22. QB×P, Q×P; 23. B×Kt, B×R; 24. B×B ch, K to B2; 25. B to QB4, Kt×B!; 26. B×Q ch, Kt×B; 27. Q to B4 and wins.

20. R to QRsq	20. Q to Q3! (best)
21. B to Kt4	21. B×Kt ch

If 21. Q to Q2 or Qsq; 22. R×KtP, followed by 23. P to Q6, and White wins.

22. Q×B	22. Q to K4 or Q2 or Qsq
22. R to Ksq or R×KtP	

and again White has a winning position.

(A.)

The following variations of the Defence 5. P to KKt4 in the Steinitz Gambit are worthy of attention:—

1. P to K4	1. P to K4
2. Kt to QB3	2. Kt to QB3
3. P to B4	3. P×P
4. P to Q4	4. Q to R5 ch
5. K to K2	5. P to KKt4

Although this Defence is seldom played, it deserves notice.

6. Kt to Q5 or varn.	6. K to Qsq
7. Kt to B3	7. Q to R4
8. K to B2	8. B to Kt2
9. P to B3	9. KKt to K2 or (B)
10. B to K2	10. P to B3
11. Kt×KtP	11. Q×Kt
12. QB×P	12. Q to R5 ch
13. P to Kt3	13. Kt×Kt
14. P×Kt!	14. Q×B
15. P×Q	15. Kt to K2
16. B to B3 and wins.	

The above moves occurred in a game in the last Divan Tourney between Gossip and Loman.

(B.)

	9. Kt to B3

Played by Tarrasch against Burn in the Frankfurt Tourney; but Steinitz prefers KKt to K2, as above analysed.

10. Kt×Kt	10. B×Kt
11. P to K5	11. B to Kt2
12. P to KKt4	12. P×P *en pass.* ch
13. K to Kt2	13. P to KR3
14. P×P	14. Q to Kt3
15. B to Q3	15. P to B4
16. Q to B2! with an excellent game.	

Variation on White's 6th move.

6. Kt to B3	6. Q to R4
7. P to KKt4	

Steinitz prefers this to 7. Kt to Q5, which, however, yields White a capital attack.

	7. Q to Kt3
8. P to KR4	8. P to B3
9. P to Q5	9. QKt to K2
10. Q to Q4	10. B to Kt2
11. Q to B5 with a strong attack.	

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